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EXTENDED-RANGE FORECASTING

The Meteorological Office Discussion, held at the Imperial College, London, on February 28, was on the experimental preparation of four-day forecasts at present being carried out in the Forecasting Research Division. The discussion was opened by Dr. A. G. Forsdyke.

Introductory.—Since September 1, 1948, the Forecasting Research Division has prepared a twice-daily series of surface and upper air charts covering a large part of the northern hemisphere. Based on these charts, and on certain other considerations to be referred to in this discussion, experimental four-day forecasts were begun, once weekly, in October 1948. The experience gained since then is considered to have justified an extension of the experiment, and since February 1, 1949 the forecasts have been prepared twice weekly, on Tuesdays and Fridays.

The necessity for charts covering the hemisphere for purposes of extended-range forecasting is generally agreed. The methods used in the experiment are, to a large extent, the same as those in the daily routine forecasting, but the emphasis is on the large-scale features of the hemispherical circulation patterns rather than on individual pressure systems. The essential feature of the work is the prominence given to the 1000–500-mb. thickness chart, and the ideas concerning development and the thermal pattern put forward by Dr. R. C. Sutcliffe[1,2]*.

Background.—We confine our attention in this discussion to medium-range forecasts covering periods of a few days, and make no attempt to deal with the extensive researches into methods of long-range forecasting covering months or seasons. Much of the research in medium-range forecasting so far carried out in this and other countries has been purely empirical. We shall not deal with those this evening, but, from the various medium-range forecasting projects, we select the following three as being best representative of the background to the present experiment :—

(*a*) the work of F. Baur in Germany from 1932 up to the second World War ;
(*b*) the work of C. E. P. Brooks in this country, 1942–44 ; and
(*c*) the work of the U.S. Weather Bureau Extended Forecast Section.

*These numbers refer to the list of references on p. 131.

Under Baur, ten-day forecasts for Germany were issued by the Research Institute for Long-Range Weather Trends, German State Meteorological Service, beginning in 1932. Baur's work was based largely on correlations with past weather, but its main interest for us lies in the fact that the statistical forecasts were modified by considerations of the " broad-weather situation ". This is rather loosely defined, but may, following Sir Gilbert Walker, be regarded as " a condition of the atmosphere which controls the weather for several days, remaining sensibly constant in spite of changes in the weather from day to day ". In Baur's work the pressure distribution at 5 Km. was most commonly taken as characterising the " broad-weather situation ", and this became associated with the idea of steering of surface pressure systems by the upper currents. Its importance for medium-range forecasting lay in that a persistent upper pressure distribution might steer a series of surface systems on approximately the same track at intervals over a period of days, thus determining the general character of the weather for the area affected.

The principal work of Brooks consisted in forecasting the mean pressure distribution over Europe and the North Atlantic for six- or twelve-day periods by the method of pressure trends. The trends were essentially estimated from pressure anomalies at a large number of stations, and though there was some appeal to physical reasoning the method was mainly empirical.

The work of the U.S. Weather Bureau Extended Forecasting Section is described in more detail below.

American extended-range forecasting methods.—These are described in a number of reports the most recent of which is by J. Namias[3]. They are based on considerations relating to the general atmospheric circulation, which is assumed to conform to the usual model ; at the surface, polar and tropical easterlies separated by the westerlies of middle latitudes ; aloft (at a sufficiently high level), general westerlies.

The strengths of those components of the circulation are indicated by circulation indices. Typical of these is the zonal westerly index, derived from the mean south–north difference of pressure between the parallels of 35° and 55°N., but expressed in metres per second by the geostrophic relation. " Normal " values of this index for the whole northern hemisphere range from about 2·2 m./sec. in winter to 0·8 m./sec. in summer. Obviously, deep Icelandic and Aleutian lows with well developed subtropical highs give rise to high values of the index ; if these systems are displaced from their normal positions or broken up so that there is a strong meridional interchange of air, the index is low. But the converse does not necessarily hold. In any case the methods of forecasting future values of the indices are entirely empirical, and they appear to be used for checking the prognostic charts rather than for their intrinsic value. The emphasis is on five-day means rather than daily values of the indices.

The closed circulations of the surface pressure pattern usually give place aloft to a series of ridges and troughs, lying very roughly from south to north, with amplitudes up to 20° of latitude or more. These systems are basic in American practice. The level of 700 mb. is selected as standard. The 700-mb. prontours are first prepared and the prebaratics derived from them, in the first instance " mechanically " using forecast thicknesses, but the prontours themselves may have to be adjusted subsequently in the light of the existing and forecast sea-level pattern. Again the main emphasis is on five-day mean ridges

and troughs, which appear to move at only about one fifth of the speed of individual systems appearing on the daily charts. Being slow moving the mean troughs are held to determine the general character of the weather over the extended period (they indicate the regions in which the individual troughs will be at their deepest).

Numerous " rules ", mostly empirical, are used for forecasting the positions of mean troughs and ridges. Among those having some physical basis are rules based on the movement of long waves (the ridge and trough system) and constant-vorticity trajectories.

Rossby[4] has shown that, under certain simplifying assumptions, the velocity of a sinusoidal wave in the zonal current is given by

$$c = U - \frac{\beta L^2}{4\pi^2},$$

where c = wave velocity
U = zonal velocity
L = wave-length between adjacent troughs or ridges
β = rate of change northward of the Coriolis parameter.

For steady state conditions, $c = 0$, stationary wave-lengths L_s we have

$$L_s = 2\pi\sqrt{(U/\beta)}.$$

The stationary wave-length increases with the zonal velocity. It follows that, for a given U, if the wave-length differs from L_s some movement of the troughs and ridges may be inferred. In practice, it is found that these formulæ require considerable empirical modification.

Under the assumption of zero divergence the vertical component of total vorticity of a moving parcel of air remains constant. Owing to the variation of Coriolis parameter with latitude, the constant-vorticity trajectory is a series of waves similar to those under discussion. In practice, the 700-mb. troughs and ridges are compared with those derived on the assumption of constant vorticity ; the differences enable convergence and divergence and hence changes in the troughs and ridges to be inferred.

Other cartographical aids are used, among them moisture-distribution charts and climatological charts, too numerous to be mentioned.

In the final stage of the work daily prognostic charts are prepared for the forecast period. It is essential, of course, that these shall average out to agree with the forecast five-day mean charts.

Forecasting Research Division Experiment.—As in the U.S.A., current surface and upper air charts of the northern hemisphere are used, but, with the limited resources available, no attempt has been made to prepare an elaborate system of auxiliary charts : our medium-range forecasting section is much smaller than its American counterpart. The main difference between the American methods and ours is largely one of emphasis and lies in the significance we attach to the thickness pattern. The essential coupling of different levels, in development, through the thickness pattern, has been stressed by Sutcliffe[1]. We regard the flow patterns at all levels as being brought into mutual relationship through the thickness pattern. The latter may indeed be partly dependent on the flow pattern insofar as it is affected by changes of temperature due to ascent and subsidence, but it depends also upon certain external influences—advection, temperature of underlying surface and radiation ; so the thickness

pattern constitutes a parameter for the hemispherical circulation, having a form to some extent independent of that circulation. The American school on the other hand treat the flow patterns at different levels as basic dynamical features and do not give quite the same prominence to their inter-dependence.

Contrary also to American practice, we have not so far used mean four-day charts either retrospectively or prognostically.

Sutcliffe[2] has discussed the relation of cyclonic and anticyclonic development to the thickness pattern and has also described other uses of thickness charts in general forecasting. To these may be added the advantage for medium-range forecasting which they have to some extent in common with Baur's broad-weather situation and the mean troughs and ridges basic in American practice, namely, that they depict a slowly moving, slowly changing pattern, through which the short-lived features move. As the tempo of changes in the surface chart limits normal forecasting to some 24–48 hr., so that of thickness changes affords some justification for attempting forecasts for the extended period.

The following circumpolar charts are prepared twice daily* on the scale 1 : 30,000,000 :—

(i) analysed surface chart ;

(ii) 1000-mb. contours and 1000–500-mb. thicknesses ;

(iii) 500-mb. contours ; and

(iv) 300-mb. contours.

These, with one or two subsidiary diagrams, constitute our cartographical aids for the experimental forecasts.

Forecasts covering the next four days are prepared twice weekly, on Tuesdays and Fridays ; at present they are essentially a research experiment, and are not distributed. Skeleton prebaratics and pre-thickness charts covering the area from the Rockies to the Urals are prepared, usually for each of the first three days of the forecast period. Their purpose is to indicate the expected trend ; forecasts cannot be given to that degree of precision which would be required by strict adherence to the prebaratics.

Experimental technique.—Full weight is, of course, given to the surface charts, which in addition to their obvious uses in applying standard forecasting technique are particularly useful for locating distant pressure systems which are potential factors for our weather over the four-day period. Track charts are prepared and used for extrapolating the paths of pressure systems over the forecast period.

Extrapolation is likewise applied to the thickness charts. Since November 1948 monthly diagrams have been prepared showing in chronological sequence the positions, at 12-hourly intervals, of the main thermal troughs and ridges along the parallel of latitude 55°N. It is evident from these diagrams that the main thermal troughs and ridges persist for at least several days. They tend as a rule to move steadily from west to east through a large range of longitude, their movement being slow compared with that of surface pressure systems ; if the geographical situation and surface circulation are favourable, thermal troughs and ridges may remain quasi-stationary for long periods.

*The 500- and 300-mb. charts are plotted twice daily but drawn up only once daily.

Two typical charts showing the movement of thermal troughs and ridges over the period February 7–15, 1949 are reproduced in Fig. 1. They show for the most part a steady eastward movement of these systems, though in the latter part of the period troughs tend to become stationary over the continents.

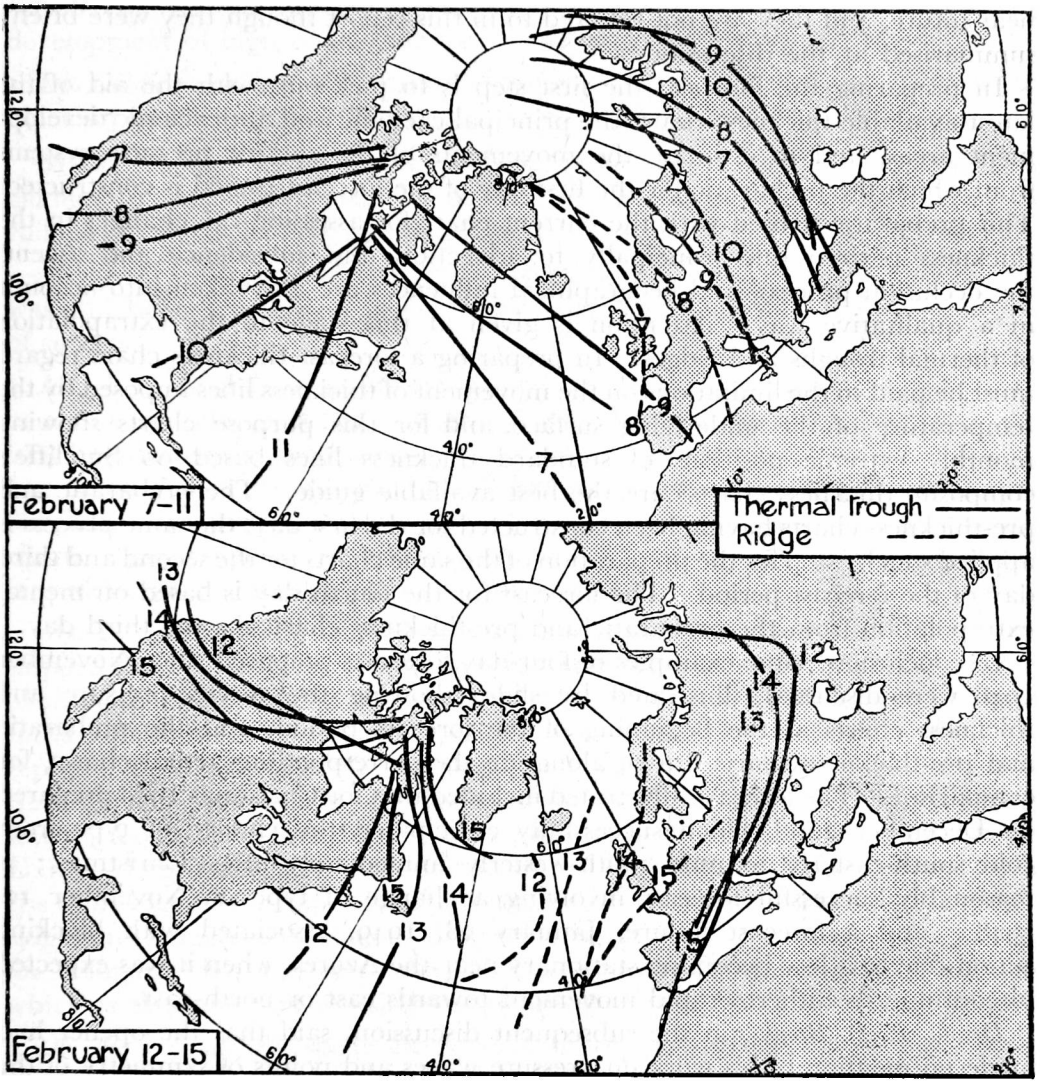

FIG. 1—TWO TYPICAL CHARTS SHOWING THE MOVEMENT OF THERMAL TROUGHS AND RIDGES, FEBRUARY 7–15, 1949

Certain circulation indices have been calculated and plotted daily since early November 1948, so far with little profit. Changes in these indices are obviously and clearly related to simultaneous changes in the general hemispherical circulation, but there is as yet no indication that they have any prognostic value. Considerations of wave-length and constant vorticity (following Rossby), intensity and latitudinal location of the main thermal gradients, and symmetry or otherwise in the hemispherical thickness pattern have a minor place in the experiment, but, so far, our ideas in these fields are vague and uncertain and their possible use must await further research.

The main forecasting tool in the present experiment is the connexion between development and the thickness pattern based on Sutcliffe's theory[1]. This is, so far as we can judge, the most important step forward in forecasting for many years. The practical implications of these ideas which are becoming increasingly widely known are being developed in papers which will be available in the near future, and they are not referred to in this report though they were briefly summarised at the discussion.

In preparing the forecast, the first step is to pick out, with the aid of the latest available thickness chart, the principal cyclonic and anticyclonic development areas, and to estimate the movements of the surface pressure systems from which the prebaratic for the first day of the forecast period is constructed. This prebaratic is used with the current chart for assessing the changes in the thickness pattern due principally to advection, but subsidence and ascent, the occlusion process, and geographical influences are also taken into account in a qualitative way. Attention is given at this stage to the extrapolation of thermal troughs and ridges. In preparing a forecast thickness chart regard must be paid to the limitations on the movement of thickness lines imposed by the temperature of the underlying surface, and for this purpose charts showing monthly extreme positions of standard thickness lines based on Sutcliffe's composite thickness charts[2] are the best available guide. The prebaratic and pre-thickness charts having been constructed for the first day, the same process is applied step by step for the preparation of the same charts for the second and third day of the forecast period. The forecast for the fourth day is based on mental extrapolation from the prebaratic and pre-thickness charts for the third day.

In conclusion, some examples of four-day forecasts prepared since November 1948 were discussed, illustrated by slides showing the surface-pressure and thickness charts at the beginning of the forecast period, and the prebaratic and pre-thickness charts drawn alongside the corresponding actual charts, for comparison. The forecasts illustrated included that for Christmas 1948 prepared on December 22nd which successfully anticipated the change of type from cold south-easterly to mild south-westerly immediately after Christmas ; a reasonably successful forecast involving a change of type on November 12, 1948 ; and a forecast failure, January 28, 1949, associated with blocking action due to a low becoming stationary near the Azores, when it was expected to continue its hitherto rapid movement towards east or north-east.

Dr. C. E. P. Brooks, in the subsequent discussion, said that the opener had made no mention of his work on pressure waves and points of symmetry of the pressure-time graph, carried out at the same time as the trend forecasts. Dr. Forsdyke, in reply, said that, having regard to the time available for discussion, he had selected the trend forecasts as being the more successful and as having the closer connexion with the medium-range forecasting experiment ; the work on pressure waves and points of symmetry was purely empirical. With this Dr. Brooks agreed, remarking however that the work on pressure waves was the more interesting.

The Director said that he was gratified to see that the Meteorological Office was using charts and parameter values for individual days instead of concentrating entirely on mean charts. Dr. Sutcliffe's work was in particular a most promising development for forecasting, all the more welcome as indicating that in this country, though not overlooking the great importance of work elsewhere, we were also working on our own ideas.

Inst. Cdr. Thorp said that during the war he was responsible for forecasts for three or more days in connexion with convoy routing. He had visited the U.S. Weather Bureau Extended Forecasting Section and had had the privilege of studying their methods of forecasting. Rossby's wave formulæ were difficult to apply in practice, but the main difficulty lay in the forecasting of blocking action—the general slowing down of the zonal circulation associated with the development of high or low pressure through a larger range of latitude.

Dr. Goldie said that observations obtained with the Bruce gun showed that blocking action extends in some cases to at least 100,000 ft.

Mr. F. A. Sharp spoke on the desirability of the examination of temperature changes at very high levels (up to 100 mb.) in forecasting the persistence or collapse of warm anticyclones and cold depressions.

Mr. J. L. Galloway said that extended forecasting using the method of Baur was still being carried on in Germany, with, however, only a limited degree of success.

Mr. A. H. Gordon remarked that, in the slides shown, the charts stopped short at about latitude 30°N., and suggested that the medium-range forecasts might well be affected by happenings in low latitudes and the analyses should therefore be carried to the equator. Dr. Forsdyke, in reply, said that the slides were for illustrative purposes only and did not include the whole of the working charts ; nevertheless the working charts were as a rule incomplete in low latitudes on account of the lack of regular data.

Mr. E. Gold said that the opener had given the impression that the analyses stopped short at the Rocky Mountains as if they constituted a complete boundary to the circulation instead of merely a barrier. An attempt ought to be made to assess scientifically the effect of the mountains on the flow pattern. In reply to Mr. Gold, after the meeting, Dr. Forsdyke said that the Rockies were certainly not regarded as an absolute boundary ; they formed a convenient starting point for estimating the flow pattern, both in this country and in the U.S.A. Empirically, regard was had to the fact that the Rockies usually give rise to a ridge in the upper flow pattern, which in turn gives rise down-stream to ridges and troughs, spaced according to the zonal velocity. There were grounds for believing that the constancy of total vorticity in a vertical air column, which is shortened on crossing the mountains, requires such a flow pattern.

Dr. R. C. Sutcliffe spoke in general terms on medium-range forecasting, stressing the desirability of experiments of the type under discussion to keep investigators alive to the realities of the problem. Unlike short-range forecasting, which was bristling with known problems, medium-range forecasting problems had yet to be formulated as a result of the experience it was hoped to gather from the experiment.

A. G. FORSDYKE

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PARTIAL THICKNESSES AS A GUIDE TO INSTABILITY

BY R. MURRAY, M.A.

The " partial thicknesses "—*i.e.* height intervals 1000–700 mb. and 700–500 mb.—of upper air isobaric charts readily depict stability and instability in the atmosphere. This fact has been known since the time such charts were first constructed, but it is perhaps generally appreciated only rather vaguely. That partial thicknesses must give some indication of stability and instability clearly follows from the correspondence between the height intervals and the mean temperatures of the air columns between isobaric surfaces.

It was considered worth while to examine the surface and upper air observations of May 1948 to see just how close was the above-mentioned relationship. The upper air observations chosen were those over the British Isles, Malta, Gibraltar, Lagens, Meeks Field and Bardufoss.

The " 700 thickness " (partial thickness 1000–700 mb.) and the " 500 thickness " (partial thickness 700–500 mb.) were correlated with the occurrence or non-occurrence of precipitation of an instability type (showers, thunderstorms, instability rains) within 3 hours of the time of the upper air ascent. All observations associated with frontal rain were omitted. Out of a total of 715 ascents there were 471 associated with the non-occurrence of instability precipitation. The remaining 244 ascents gave instability precipitation occurring within a radius of about 100 miles of the station (in 140 of these precipitation occurred at or within sight of the station concerned). The choice of the time interval $\pm$ 3 hr. and of the area of 100-miles radius, together with the representation of instability by the occurrence of instability precipitation is somewhat arbitrary, but seems reasonable.

With abscissæ and ordinates the 700 and 500 thicknesses respectively, Fig. 1, showing the non-occurrence of instability precipitation, and Fig. 2, showing the occurrence of instability precipitation, were then constructed. In Fig. 1 line *aa* was tentatively drawn so that about 95 per cent. of the observations were on or above it. In Fig. 2 line *bb* was drawn so that about 95 per cent. of the observations were on or below it. It is thought that lines *aa* and *bb* would be in only slightly different positions if many more observations were used in the construction of Figs. 1 and 2 than in this sample of 715. Hence it is suggested that the graphs may be used in making a rough yet useful assessment of stability and instability from upper air charts. Above *bb* refers to stability ; below *aa* refers to instability. A point falling between *aa* and *bb* indicates uncertainty as regards stability or instability, thus suggesting that a more detailed consideration of the upper air structure, especially the moisture distribution and the exact height and intensity of temperature inversions, is called for.

The near-straight line *cc* was constructed from the 700 and 500 thicknesses associated with the moist adiabatics on the tephigram. As a first approximation it might be assumed that *cc* represented a sort of neutral line, and that points above and below *cc* referred to stability and instability respectively ; but facts appear to indicate that a much better neutral line must lie between *aa* and *bb*, and thus have less slope than line *cc*. One of the reasons for this is probably that instability phenomena can usually develop in a shallower unstable layer in cold air (where the freezing level is low) than in warm air.

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EVENING AFTER A DAY OF DRIZZLE ON THE ATLANTIC

During July 15, 1948 a small wave on a feeble front passed through station JIG (53°50′N. 18°40′W.) giving periods of slight drizzle but without giving any marked change in temperature or dew point, and hardly ever a completely overcast sky. This photograph was taken after the weather had begun to improve and shows precipitation falling from banks of nimbostratus with patches of altostratus, altocumulus and cirrus above.

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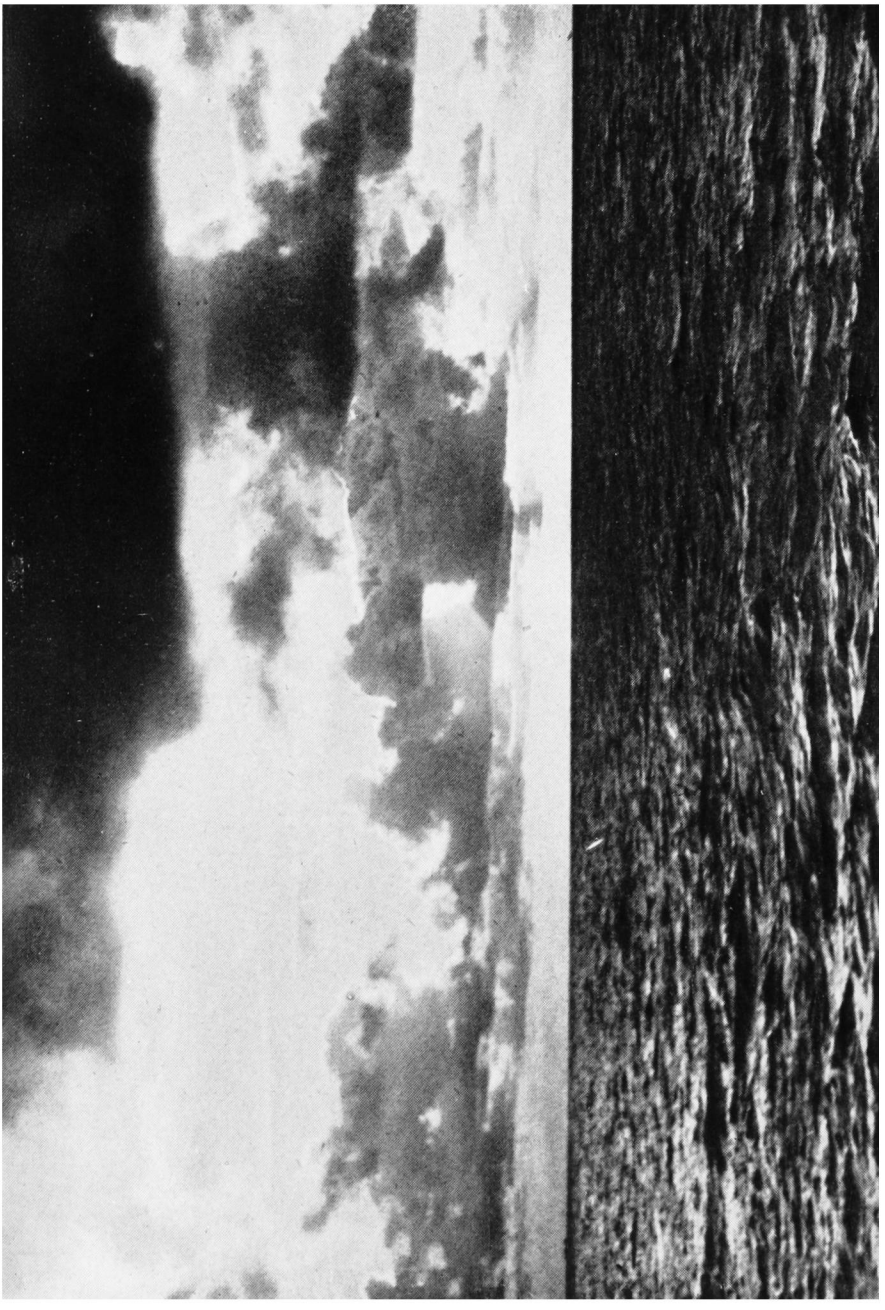


Reproduced by courtesy of O. M. Ashford

EVENING ON THE ATLANTIC IN POLAR AIR

This photograph, taken towards sunset on July 20, 1948 at station JIG shows the typical sky with large cumulus and good visibility associated with unstable polar air.

It may be argued that, because upper air ascents are already available, to use partial thicknesses in estimating stability and instability is like putting the cart before the horse. But there is more to it than that. The idea is of some practical use in relation to both (1) actual and (2) forecast charts.

(1) The vast amount of general information to be assimilated by the forecaster makes it of some importance to have the broad picture of stability and instability in a handy form—*i.e.* already on the upper air charts through the relation between the 700 and 500 thicknesses given by Figs. 1 (or 2). The forecaster is thus able to see at a glance which regions have ascents requiring more critical analysis—the unnecessary checking of all tephigrams is thereby avoided.

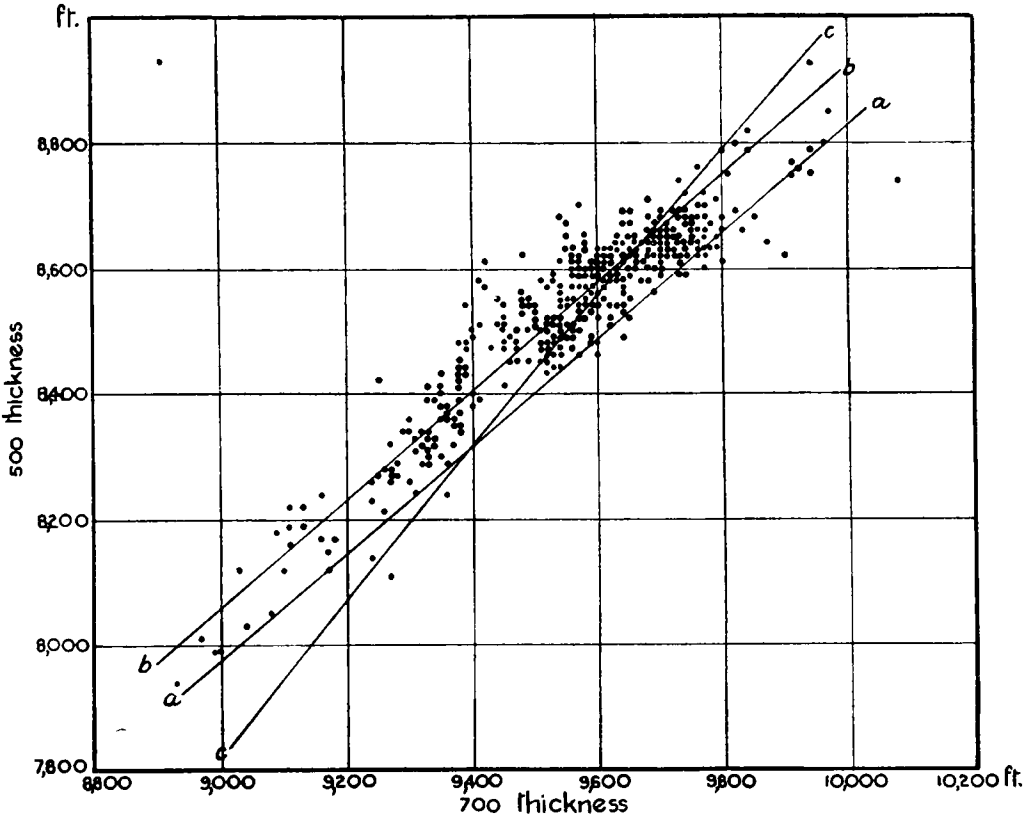


FIG. 1—VALUES OF 700 THICKNESS AND 500 THICKNESS WHEN INSTABILITY PRECIPITATION DID NOT OCCUR

112 additional observations at points already marked, 2 of these falling below line *aa*.

Reversing the argument, regions of marked instability (as indicated by Sferic reports, say) may be known where no upper air ascents are available (*e.g.* the 0900 and 2100 G.M.T. soundings are rather scanty over Europe), so that the forecaster in constructing his upper charts must ensure that the 700 and 500 thicknesses are drawn in such a way as to be consistent with the known occurrence of instability, thus ensuring accuracy in the absolute contours because these are so dependent on the partial thicknesses.

(2) Stability changing to instability, or *vice versa*, can best be anticipated from a consideration of the partial thicknesses on the upper air charts. In this

connexion differential advection, differential heating, the movement of cold or warm pools are of importance.

For instance, using the thickness diagram, it may be found that the 700 and 500 thicknesses intersect between the lines *aa* and *bb*, and a check of the actual ascent shows little instability. Suppose now that the upper air charts indicate that the 500 thickness is increasing relative to the 700 thickness (say, because the 500 thickness is warming due to subsidence and/or advection), then clearly the air is becoming more stable. On the other hand, it may be that a decrease in the value of the 500 thickness is indicated (say, because colder air is being advected at upper levels or because the air at lower levels is becoming

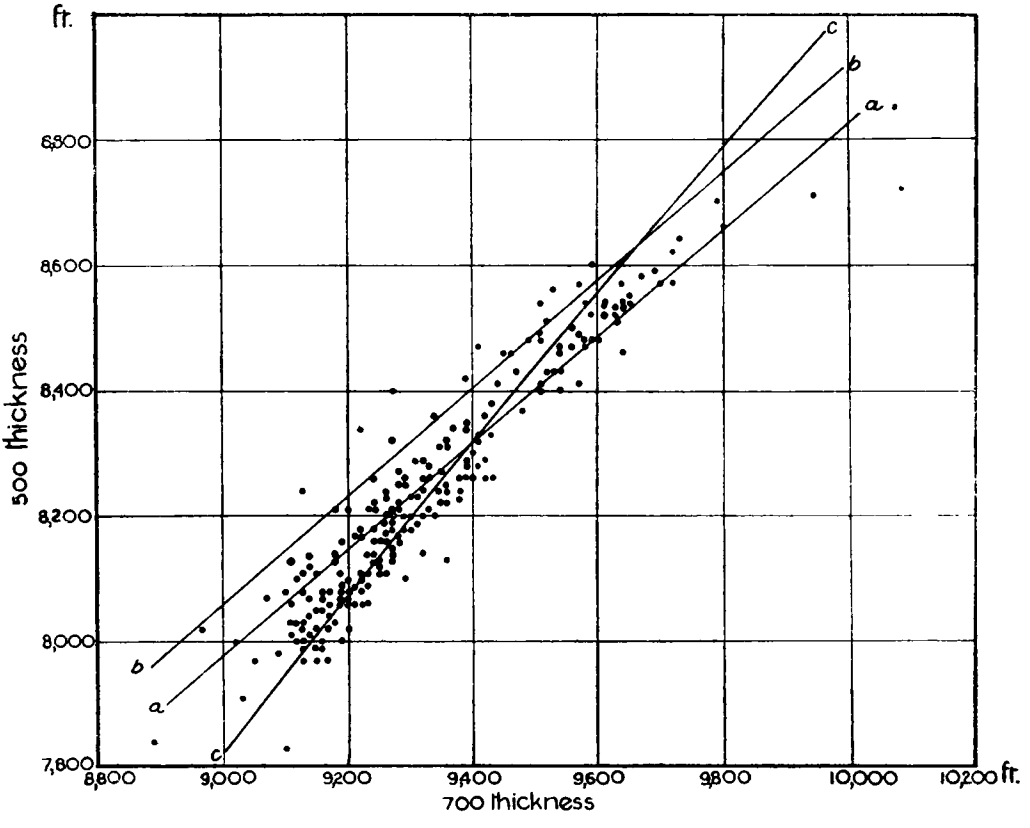


FIG. 2—VALUES OF 700 THICKNESS AND 500 THICKNESS WHEN INSTABILITY PRECIPITATION DID OCCUR

36 additional observations at points already marked, none above the line *bb*.

warmer through advection and/or surface heating), and the air is becoming more unstable ; and the probable development of instability precipitation must be considered if the expected change is sufficiently great.

It may be mentioned that the Prontours (the forecast upper air charts issued by the Central Forecast Office) contain inherently the 700 and 500 thicknesses, so enabling an assessment of stability and instability to be made, but no official routine forecast of particular upper air ascents is issued.

One word of warning is necessary. Instability in a comparatively shallow layer below 700 mb. may be sufficient to cause some precipitation (normally of slight intensity) ; then the value of the 500 thickness is immaterial so that the underlying idea in this note will be invalid.

REPORT ON AN EARTH TREMOR IN EAST ANGLIA ON MAY 28, 1948

BY L. L. ALEXANDER

An earth tremor was experienced at Mildenhall, Suffolk, at 17h. 02m. 30s. G.M.T. on May 28, 1948. It was sufficiently strong to be the cause of conversation amongst the local population and preliminary enquiries showed that it had been felt over a fairly wide area. To investigate the area over which it had been felt, the public were requested through the press to send their experiences of the tremor to the Meteorological Office at Mildenhall. The notice appeared in most of the local papers in East Anglia and in *The Times*, *Daily Herald* and the London evening papers. A total of 232 replies was received by telephone and letter. These observers ranged from the head of a Cambridge college to housewives and schoolboys.

So that an estimate could be made of the scale of shock felt by each observer, the following table was devised:—

Force 1 Rumbling or slight vibration
Force 2 Rumbling or moderate vibration
Force 3 Rumbling or heavy vibration
Force 4 Rumbling accompanied by slight vibration
Force 5 Rumbling accompanied by moderate vibration
Force 6 Rumbling accompanied by heavy vibration
Force 7 Articles fell from shelves or slight structural damage.

It should be noted that this scale is designed to meet the needs of this particular earthquake which were very small; it is not therefore directly comparable with other existing scales.

This scale has been used to plot the reports in Fig. 1 together with the number of such reports, *e.g.* 3/1 indicates that three reports were received from the place shown on the map, each reporting slight vibration or rumbling. Where slight damage has been caused or articles have fallen from shelves, the report has been surrounded by a ring—there were two reports of goods falling from shelves in shops at Downham Market and one report of a cracked wall. Only two other reports of falling articles were received, from Felixstowe and from near Sudbury.

Only a small percentage of observers gave an estimate of the length of duration of the tremor and these varied considerably. Less than five seconds is generally agreed by most capable observers in the area to be the nearest estimate of the duration.

The question as to whether the rumbling preceded the vibration or *vice versa* or whether they were completely coincidental was also investigated but no satisfactory figures were obtained. Eight per cent. of observers wrote on this question—4·5 per cent. gave the rumbling preceding the vibration and 3·5 per cent. the vibration first—with no general agreement in any particular district.

The area in which the shock was felt was bounded by Peterborough–Kings Lynn–Lowestoft–Felixstowe–Bradwell Bay–Kettering. The rough centre of this area is Thetford. The area of greatest violence was in and near Downham Market.

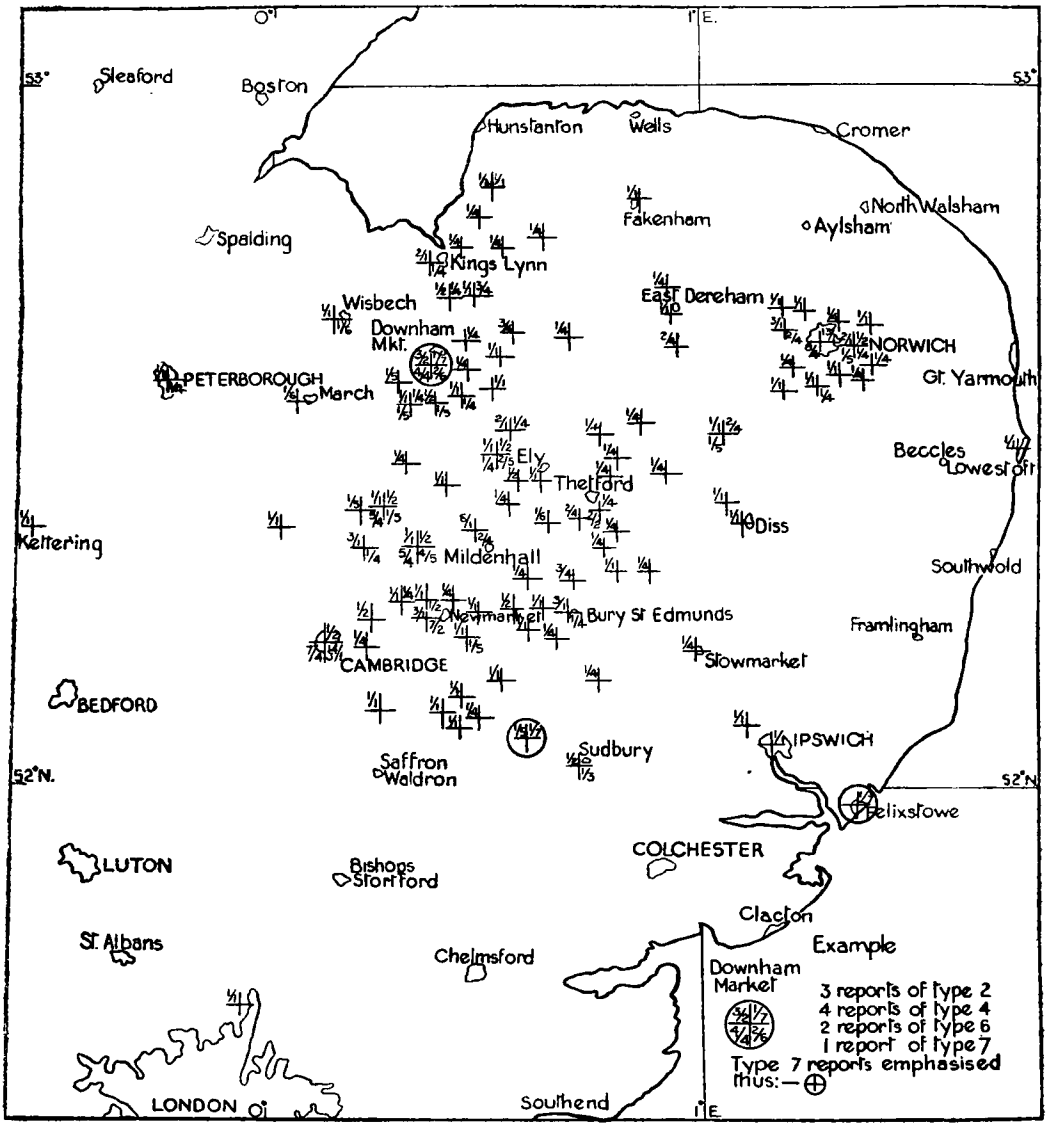


FIG 1—ANALYSIS OF REPORTS OF EARTH TREMOR ON MAY 28, 1948

ANALYSIS OF REPORTS

	Rumbling or vibration only	Both rumbling and vibration
Cambridge	19	10
Ely	14	18
Downham Market	6	12
Kings Lynn	12	16
Norwich	24	17
Thetford	6	21
Bury St. Edmunds	13	14
Newmarket	8	7
Ipswich	2	0
Outlying areas	9	4

Mostly the rumbling was described as " like thunder ", although several reports state that a loud crack like an explosion preceded the rumbling. This " explosion " was not peculiar to any district. The vibration was mainly likened to the passage of a heavy vehicle or to the vibration caused by a bomb exploding in the vicinity. Both were of sufficient intensity to cause alarm to women and children in a number of places.

The barograms at Mildenhall each show a small downward movement of the pen at approximately 1700 G.M.T.; the shock was not registered by any other barograph in the vicinity.

The Kew seismographs, both short-period and Galitzan, clearly showed the compression wave of this disturbance at 17h. 02m. 53s. and the distortion wave at 17h. 03m. 07s. G.M.T.; the disturbance was therefore located about 120 Km. from Kew. No record has been received of any other recording of the tremor by seismic instruments.

Extracts from typical letters received are shown as an indication of classification.

Example 1—Classified as Force 1

From Miss P.M., Cambridge.

. . . I am a patient at the above Nursing Home and on Friday last, I felt a distinct vibration as I lay in bed. . . .

Example 2—Classified as Force 2

From Mrs. P. V. H., Downham Market.

. . . We live on the upper storey of an old building and at the time I was sitting with my child in our sitting room listening to the news on the B.B.C. Suddenly our cosy stove started to rattle and then my chair and the whole room shook and swayed as I counted up to 5 or 6 (I have previously been in an earthquake in India and I recognised it to be an earth tremor). For some little time afterwards various ink bottles and ornaments rattled on my desk. For how long I can only guess as by this time I was attending to my child who was very scared. . . .

Example 3—Classified as Force 4

From Mr. F. A. S., Soham.

. . . I was on duty in the signal box at Soham station when there was quite a rumbling noise like thunder also the windows rattled violently. . . . Talking on the subject to the Train Control Office at Cambridge some half hour later, I was told that quite a number of signalmen had reported the happening. . . .

Example 4—Classified as Force 5

From Mrs. M. McG., Cambridge.

. . . when I heard what I thought was a heavy bomb falling at a great distance. The tremor was so disturbing that I felt physically sick, a similar reaction to that experienced by me during the London blitz. . . .

Example 5—Classified as Force 1

From Mr. A. F., Kings Lynn.

During the Dog Watches on 28th May, the writer being indoors at the

time experienced a long distant roar (duration approx. 10–15 seconds) time not noticed. No physical vibration felt or noticed.

Example 6—Classified as Force 7

From Mr. E. R., Downham Market.

. . . when I heard a rumbling noise and it knocked some things off my shop shelf. . . .

Mr. H. V. Shaw of West Bromwich has kindly supplied the following extracts on past seismic activity in East Anglia; they are taken from " A History of British Earthquakes " by Charles Davison.

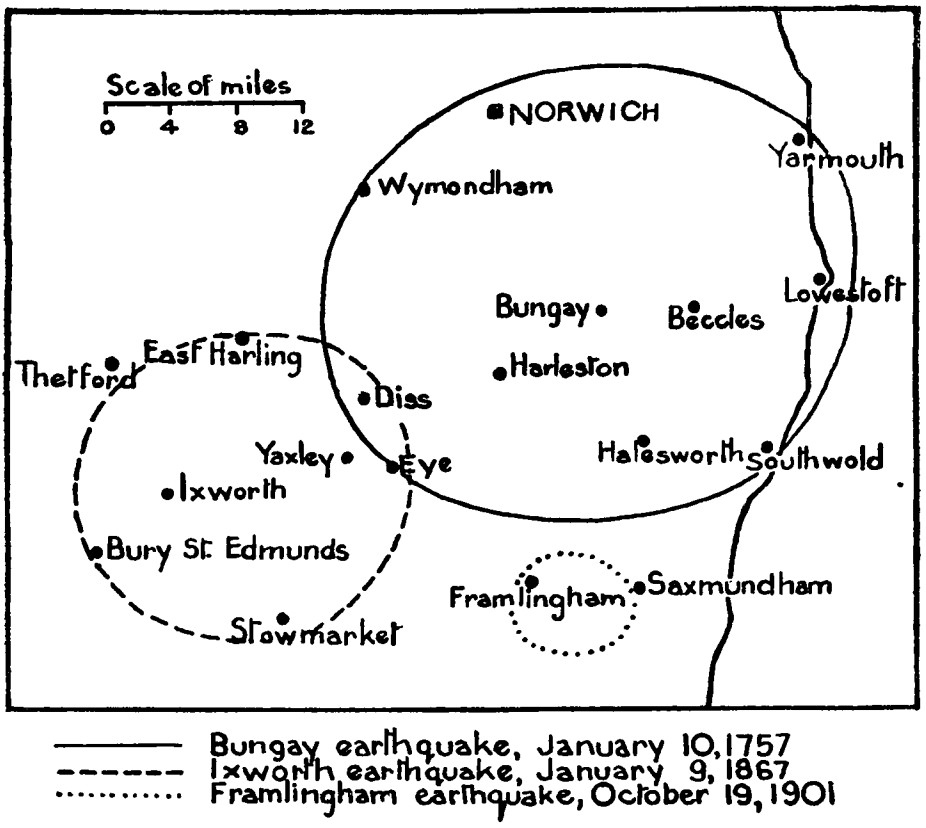


FIG. 2—ISOSEISMAL LINES OF THE BUNGAY, IXWORTH AND FRAMLINGHAM EARTHQUAKES OF 1757, 1869 AND 1901

1757, *January* 10. Centre of disturbed area in 52°29′N. 1°26′E.

The boundary of the disturbed area is represented approximately by the continuous black line in Fig. 2. It is 32 miles long, 27 miles wide, and contains about 680 square miles. Its centre lies 1 mile north of Bungay, and the longer axis is directed a few degrees north of east.

1869, *January* 9—Intensity 4*—Centre of disturbed area in 52°18·1′N. 0°57·4′E., 14 records from 11 places.

The disturbed area, the boundary of which is represented by the broken line in Fig. 2, is 20 miles long from east to west, 18 miles wide, and contains

*These intensity numbers refer to a modification of the Rossi-Forel Intensity Scale, Intensity 4 indicating " windows, doors, fire irons, etc. made to rattle."

about 280 square miles. Its centre is at the village of Walsham-le-Willows or 9 miles south of East Harling.

The shock consisted of a quiver, accompanied by a rumbling sound like thunder or the rapid passing of a heavy carriage. At Yaxley and West Harling, pheasants crowed and flew from the gound in alarm.

1901, *October* 19.—About 7.25 p.m.—Intensity 4*—Centre of isoseismal 4 in 52°12·6′N. 1°15·0′E., 18 records from 11 places and 27 negative records from 23 places.

The isoseismal 4 is represented by the broken line in Fig. 2. It is nearly circular, 6½ miles long from east to west, 6 miles wide, and contains 31 square miles. Both shock and sound were observed at Rendlesham (2½ miles south of the isoseismal) and the sound was also heard, but no shock felt, at Dennington (1 mile north-west) and Earl Soham (3 miles west).

The centre of the isoseismal lies 1 mile south-west of Swefling and 15 miles north-east of Ipswich. There was a sudden shock followed by a brief tremulous movement lasting a few seconds. The sound, usually of brief duration, was heard by all the observers.

1901, *October* 22.—About 9.15 a.m.—Intensity 4—Centre of isoseismal 4 in 52°12·7′N. 1°15·2′E., 22 records from 13 places and 27 negative records from 23 places.

The isoseismal 4 coincides very nearly with that of the preceding earthquake. The shock and sound were observed at Earl Soham, the shock was also felt at Snape (1 mile south-east of the isoseismal) and the sound was heard at Cretingham (3½ miles west). The shock was similar to that of the first earthquake, consisting of one prominent vibration followed by tremulous motion and lasting altogether about 3 sec. In 15 out of 17 records, the sound was compared to types of short duration.

METEOROLOGICAL RESEARCH COMMITTEE

The fifth meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on March 3, 1949.

Two papers, " The relation between the standard deviation of temperature at constant pressure and at constant height " by A. F. Crossley and " Report on some synoptic studies of atmospheric dynamics " by J. S. Sawyer, were considered.

Papers on dynamic instability, ageostrophic motion ahead of warm fronts and the relation between wind and the pressure field in the tropics, were also discussed.

OFFICIAL PUBLICATIONS

The following publications have recently been issued.

BRITISH RAINFALL 1946

This publication, the eighty-sixth in the series and the first to appear since 1939, retains the essential features of pre-war issues, although paper shortage has necessitated some curtailment and re-arrangement. The volume is a comprehensive summary of the rainfall of 1946, both as regards its incidence during

the year and its variation from place to place. The records of about 5,000 observers are discussed with the aid of numerous maps and tables.

The book is arranged in two parts :—

Part I consists of eleven chapters under the headings : The work of the British Rainfall Organization, The distribution of rainfall in time, Droughts and dry spells, Rain spells and wet spells, Duration of rainfall, Heavy falls in short periods, Heavy falls on rainfall days, Monthly rainfall, Seasonal rainfall, Total rainfall in 1946, Evaporation and percolation.

Part II is the General Table of Rainfall and gives the recorded total fall with the numbers of rain days and wet days at about 5,000 stations in Great Britain and Northern Ireland, together with the names of the observers or other authorities.

Two volumes, still to be published, will contain data for the war years : the first, for 1940, 1941 and 1942, and the second for 1943, 1944 and 1945.

METEOROLOGICAL REPORTS

No. 2—Aviation meteorology of the Azores

Standing as they do midway between Europe and America the Azores have attained a new importance with the coming of regular transatlantic flight. Their rugged peaks, moreover, are breeders of cloud and weather with a meteorological interest that has unique features. To the forecaster in western Europe who uses the Azores observations as one of his main supports in synoptic analysis the correct interpretation of those observations is vital.

On all these counts the publication of a full report on the meteorology of the Azores is very welcome, particularly when it has been compiled by officers who have had considerable experience of the difficulties of forecasting the vagaries of the weather of these islands.

ROYAL METEOROLOGICAL SOCIETY

Large-scale vertical motion in the atmosphere was discussed at a meeting of the Society held at 49, Cromwell Road, South Kensington, on February 16, Sir Robert Watson-Watt, President, in the Chair.

The discussion was opened by Mr. J. K. Bannon who first remarked briefly on the importance of vertical motion in atmospheric dynamics and the difficulties in measuring or deducing it. He then went on to describe a method of estimating up-currents from the rate of rainfall*. In an ascending cloud mass in which conditions do not vary greatly in the horizontal and when the up-currents are not large enough to support small raindrops, the cloud particles do not contain much water (or ice) and hence the rate of release of precipitation from the ascending cloud is, to a good degree of accuracy, the rate at which the saturated water-vapour content of the air decreases as the temperature falls due to adiabatic expansion. Thus when the temperature structure of the air is known and also the base and top of the ascending current of air, rate of rainfall measurements on the ground (allowing for any evaporation of the rain as it falls)

*BANNON, J. K. ; The estimation of large-scale vertical currents from the rate of rainfall. *Quart. J. R. met. Soc., London*, **74**, 1948, p. 57.

may be used to calculate the mean up-current in the cloud mass. Results obtained from rainfall records in the Hebrides show that up-currents of 10 to 20 cm./sec. are usual in typical North-Atlantic depressions.

Mr. J. S. Sawyer then described two methods of deducing vertical movement in the atmosphere. The first method, due to Graham*, depends on being able to trace the horizontal movement of the air so that the position of a particular parcel of air at the time of one upper air temperature observation is known at the time of the previous temperature soundings ; any difference at a fixed level between the observed temperatures of approximately the same parcel of air is assumed to be due to vertical motion with adiabatic changes and hence the vertical velocity is inferred. The second method depends on the approximate relation between rate of change of vorticity and the divergence of the horizontal wind field (the vorticity equation) and the relation between this horizontal divergence and the vertical motion (the equation of continuity). Using the geostrophic wind as an approximation to the true wind it is thus possible to deduce the field of vertical motion from pressure charts. In spite of the many approximations, results by this method are self-consistent and agree with observed phenomena (up-currents in rain areas, down-currents in anticyclonic areas); they also agree qualitatively with results obtained by Graham's method.

Professor P. A. Sheppard gave an interesting account of some work being carried out under him at Imperial College, by Mr. H. A. G. Van Ufford and others. The eight wind-finding stations in the British Isles are the apexes of seven triangles with sides of length about 200–300 miles. The horizontal divergence over each of these triangles was evaluated from the winds observed at the corners (specially supplied by the Meteorological Office to the nearest degree in direction and nearest knot in speed), at 100-mb. intervals between the levels 900 mb. and 200 mb. (*i.e.* approximately from 3,000 to 40,000 ft.) for all possible occasions in the period December 1947 to February 1948, inclusive. These measures lead immediately to the vertical velocities at these levels by the equation of continuity.

Analysis of the results was not complete but Professor Sheppard demonstrated some preliminary conclusions. Curves were shown giving the distribution with height of the mean up- and down-currents for the triangle Larkhill-Liverpool-Downham Market for January 1948 ; when there was general ascent below 500 mb. the maximum velocity (between 7 and 8 cm./sec.) occurred at about 16,000 ft.; with general descent in the troposphere the maximum (between 6 and 7 cm./sec.) occurred at about 20,000 ft. In both cases the mean vertical velocity at the tropopause (up and down respectively) was about 4 cm./sec. Up and down velocities of up to 30–40 cm./sec. were deduced in particular cases even in the lower stratosphere.

Mr. M. K. Miles compared vertical velocities he had worked out for one occasion by three different methods. The velocities deduced by a direct method (from observed winds) and by Bannon's method were comparable, but that by Graham's method was much smaller, probably because the latter was an average over 6 hours.

Dr. R. C. Sutcliffe welcomed the attack on the vertical-motion problem, one of the central problems of meteorology, and was particularly enthusiastic

*GRAHAM, R. C. ; The estimation of vertical motion in the atmosphere. *Quart. J. R. met. Soc., London*, **73**, 1947, p. 407.

about Professor Sheppard's work. He advocated the fullest use of the British-Isles network of upper air observing stations (the best in the world) to discover the basic facts about typical weather situations ; models, so determined, could then be applied to similar weather types in other parts of the world.

Professor Sheppard, in answering a question from Mr. C. S. Durst, said that since winds measured by radar methods were means over a depth of about 3,000 ft., the small variations in wind, which L. F. Richardson thought would make numerical analysis impossible in some cases, were smoothed out. He had never obtained a ridiculous or inconsistent result by his method.

Mr. O. M. Ashford pointed out, as noteworthy, that the vertical velocities as deduced by Professor Sheppard showed no discontinuity at the tropopause.

Sir Robert Watson-Watt, in concluding, emphasised the importance of quantitative results in meteorology as in other sciences, and said that he thought the results demonstrated during the discussion showed exciting progress.

MICROMETEOROLOGY IN AMERICA

On February 24, Professor O. G. Sutton gave a talk to members of the staff of the Meteorological Office regarding his visit to the U.S.A. in the Autumn of 1948. The following is a brief account of this talk.

Professor Sutton began by saying that, up to 1939, the United Kingdom was in a better position regarding knowledge of micrometeorology than anywhere else in the world, thanks chiefly to the excellent basis established by Sir Nelson Johnson when he was in charge of the Meteorology Section at the Experimental Station, Porton. This was not an idle claim, but one that had been amply substantiated by war-time conferences with meteorologists from other countries and by the post-war examination of captured German documents. Since the cessation of hostilities there had been a growing interest in this aspect of meteorology, and it was particularly heartening to know that the United States, with its vast scientific potential and acknowledged leadership in technology, was now taking a much deeper interest in the subject than heretofore.

The speaker then explained that he had been granted leave of absence from his academic duties by the War Office to accept an invitation from the U.S. Weather Bureau to deliver a course of lectures on atmospheric turbulence at Washington, and to advise on certain problems which are now being investigated at various centres in America. Originally, it had been intended that some lectures should also be given at the University of Chicago, the Massachusetts Institute of Technology and New York University, but, owing to difficulties caused by the dock strike, it was possible only to fulfil the engagement at New York.

The field covered by the lectures was briefly as follows : first, a general account of turbulence from the aerodynamical aspect, followed by a résumé of facts concerning the meteorology of the lower atmosphere. The lectures then dealt briefly with the familiar " classical " theories and the reasons for their failure, and went on to describe attempts to produce a workable theory by making K vary with height according to empirical laws. The modern era starts with the introduction of mixing-length theories and thence to the statistical approach, regarded by many as the most promising yet evolved. A considerable amount of time was devoted to discussing the problems of diffusion and evaporation, and the course concluded with an account of turbulence

in a variable density gradient and the problems associated with convection. The lectures were well attended by a keen and critical audience, whose enthusiasm made the task of the lecturer thoroughly enjoyable.

Professor Sutton then went on to discuss points of interest from various projects now in active development. He mentioned investigations into upper air turbulence being made by a team working under Dr. Harry Wexler, with the object of extending our knowledge of long-time-scale diffusion, on lines initiated in England by Richardson and Proctor. He described the activities of the Meteorology Group at Brookhaven, Long Island, and dwelt at some length on the elaborate and finely executed instrumentation employed, including two 420-ft. towers, one of which carries wind, temperature and humidity elements at frequent intervals so that a very detailed picture of the profiles can be obtained at any time. This work is directed by Dr. Norman Beers, and has as its primary aim the study of micrometeorology in relation to the dispersion of effluent from stacks.

Considerable interest was aroused by the lecturer's description of the means adopted for investigating in detail the temperature field near the ground at Camp Detreck, Maryland, again in connexion with the dispersion of smoke. The temperature-measuring elements in this case are very small thermocouples, which are used unscreened and without artificial aspiration, a preliminary investigation having shewn that the customary precautions are unnecessary with such small elements. This work, which is in charge of Major Suggs, is still in its early stages but shews excellent promise of producing results of the greatest interest. The lecturer was greatly impressed by the excellent quality of the recording obtained, the combination of quick-response instruments and photographic records giving a very vivid picture of the fluctuations of air temperature near the ground.

During Professor Sutton's stay in the States public attention was drawn to the problems of atmospheric pollution by a disaster at the small industrial town of Donora, near Pittsburgh, Pa. The speaker was invited to discuss the matter with the Industrial Hygiene Foundation of Pittsburgh, and he explained the difficulties involved in attempting to reconstruct what actually happened in the valley during the " smoggy "* days with inadequate meteorological data, the nearest weather station being at Pittsburgh Airport, about 20 miles away. Other problems discussed while in America included one relating to the design of a power station in the vicinity of a busy commercial airfield, where the chimneys cannot be made very high. Finally, the speaker drew attention to a purely statistical method of dealing with the " smog " forecasting problem. This has been developed for the Los Angeles area and consists essentially in watching the movements of the 700-mb. surface in relation to wind anomalies.

In conclusion, Professor Sutton said that his stay in the States had been most enjoyable and inspiring, and that he felt sure that in a very few years, American enterprise and skill would mean significant advances in micrometeorology.

The discussion which followed was animated and keen interest was shewn in many aspects of the work, particularly that relating to the measurement of temperature.

*" Smog " is a U.S. abbreviation for " smoke fog."

ROYAL SOCIETY OF ARTS

Two lectures were recently delivered at the Royal Society of Arts on subjects of interest to meteorologists.

The first was given by Lt. P. G. Satow, D.S.C., R.N., on January 4 and was entitled " The application of radar to the science and art of maritime navigation ". Lt. Satow very ably sketched the history of the marine radar and how its war-time use primarily for the detection of enemy craft was readily adapted for navigational purposes. Like so many war-time inventions its use in peace time has turned out to be very great and, if intelligently used, it can be an enormous asset to the navigator. Lt. Satow very clearly described the principle of the instrument and illustrated the types at present in use in merchant ships. He pointed out the limitations of the instrument and emphasised that, even if a ship was fitted with radar, the navigating officer still had the same need of sea sense and seamanship as of old.

In discussing the limitations of the instrument Lt. Satow led up to the meteorological conditions affecting radar. He pointed out the enormous ranges which are obtained as the result of freak propagation and the sudden reductions in range which can occur as a result of thunderstorms, frontal situations, heavy rain and the like. He very ably illustrated these meteorological conceptions with the use of slides giving typical cloud formations followed by weather maps and photographs of radar displays in which the interference due to weather was very clearly shown.

Finally, Lt. Satow demonstrated the use to which radar could be put from a hydrographic point of view, illustrating with the use of charts the remarkable detail of topographical features that a radar scan can pick up.

The second lecture was given on January 11 by Captain J. W. Josselyn, D.S.C., R.N. (retd.), lately Director of the Naval Meteorological Service. Captain Josselyn's lecture was entitled " Weather forecasting at sea " and was designed to illustrate the type of information that the forecaster at sea was likely to be asked for and the limitations in the material at his disposal. Captain Josselyn discussed not only the naval point of view, but also that of the merchant seaman and stressed that, in brief, wind, state of sea and visibility were the three items with which the seaman was chiefly interested. He pointed out that with the collective broadcasts that were issued nowadays the seaman or professional forecaster aboard a ship could prepare his own charts, and, with the addition of information from his own and other ships in the vicinity, build up quite a comprehensive picture of the weather situation and issue quite a reasonable forecast.

For the benefit of those present who were not meteorologists, Captain Josselyn briefly sketched the life history and theory of temperate zone depressions and the principle of air masses. He illustrated cases where the seaman could, by using surface data alone, make quite reasonable forecasts of impending weather, but emphasised, at the same time, the value of upper air data when this is available. He went on to discuss the formation and movement of tropical storms and methods of forecasting these, and illustrated some unusual tracks of these storms.

After discussing the forecasting of visibility at sea, Captain Josselyn wound

up by illustrating the relative simplicity of the forecaster's work at sea compared with that of his colleague ashore who, admittedly, had more material at his disposal, but who had to serve many more varied interests.

C. E. N. FRANKCOM

LETTERS TO THE EDITOR

Barograms from big ships

Mr. Bibby's comment on my letter appearing in your issue for February 1949 calls for some further information from me.

Conditions on board the 15,000-ton whale-factory ship *Balaena* near the edge of the southern ice were ideal for studying the effects of gusty winds and heavy seas separately. Heavy seas broadened the barograph trace even when the wind at the ship was light, but fine traces were obtained with gusty winds of up to force 6 and over so long as the sea was calm (owing to shelter given by ice).

There was no such opportunity to distinguish and isolate the various factors contributing to the motion of the pen arm when high seas were running. By far the main factor, to all appearances, was the purely mechanical acceleration associated with the motion of the ship, and other contributions such as pressure oscillations accompanying the swell seemed to be of much less account.

My impression is that the oscillations of the pen arm of the barograph were always in phase with the motion of the ship. The instrument was set fore and aft in the vessel, and with heavy swells coming beam-on the rolling of the ship carried the pen regularly back and forth between the chart on the drum and the glass of the case. The trace was always broad at these times and of similar breadth to that produced by the swinging of the pen arm in heavy seas accompanied by pitching of the vessel without much rolling.

H. H. LAMB

March 1, 1949.

The statistician in meteorology

I have read Dr. Sutcliffe's exhilarating article on forecasting research in the *Meteorological Magazine* for March 1949. I am sorry to note his desire to squeeze out the statistician.

I feel this comes from a misconception of the role of the statistician in scientific research. Statistics is the science of handling large numbers of observations. Where there are so many observations that it is difficult to comprehend their significance then statistical analysis seeks to express the properties of the mass of data in a simple and easily understood form. If the research worker has a theory which he wants to test experimentally, statistical analysis will tell him if his data supports his theory strongly or weakly and give precise limits to the accuracy of any parameters he may be estimating. It is true that statisticians estimate correlation coefficients and regression equations but it is far more important for them to say whether the relationships derived are significant and to give the degree of confidence to be placed in the estimates.

Statistical analysis is not a method to be used when the mathematician or theoretical physicist has failed to evolve a theory, but a powerful tool whereby the research worker can put his theory under test and see just how well experimental evidence supports the theory.

G. A. TUNNELL

March 30, 1949.

NOTES AND NEWS

"Lee thermal" depressions over south-east Scotland, July 14–15, 1948

On both July 14 and 15, 1948 the only parts of the British Isles affected by thunderstorms were in south-east Scotland where "lee thermal" depressions developed in a northerly air stream which had crossed the mountains. Lee depressions or troughs of low pressure are not uncommon in that area, but only occasionally are conditions also favourable for thunderstorms, and still more rarely are thunderstorms confined to that area on two consecutive days.

A depression centred west of Iceland on July 10, 1948 had moved slowly to the North Sea by the 13th with little change of pressure at the centre. By midday of July 14 a trough of low pressure had formed across south Scotland in the northerly air stream which covered the whole of the country. Stratiform cloud persisted all day on the 14th in north Scotland and over most of England and Wales, with temperatures remaining below 60°F. and less than two hours' sunshine at most places. In the Central Lowlands of Scotland, however, the stratus broke up during the morning. There were 8·5 hr. sunshine at Leuchars, Fife, and 8·6 hr. at Renfrew (near Glasgow). Temperature reached 68°F. at both places, compared with only 57°F. at Lossiemouth and Rattray in the same air mass to the north and at Tynemouth to the south. A thunderstorm occurred at Donibristle, Fife, during the evening.

The trough of low pressure over south-east Scotland on the morning of July 15 intensified by surface heating and developed into a well marked "lee thermal" depression by midday. It attained its maximum intensity by mid afternoon, continued as a centre of low pressure until the evening and died out again at night. At Leuchars a surface wind veer from E. by S. force 3 at 1200 to SW. by S. force 3 at 1300 G.M.T. indicates that there was enough gradient wind at that time to overcome the sea breeze. The wind remained between SW. and S. from 1300 to 1500, veered to W. by N. force 2 at 1600 and then settled down to a light E. or NE. drift. Charts at three-hourly intervals over the period 0600–2100 G.M.T. are given in Fig. 1.

Temperature readings of 70°F. at Leuchars and Renfrew on July 15 were the highest reported throughout the British Isles—more than ten degrees higher than in the north and the extreme south of Scotland. Dalwhinnie, 1,176 ft. above mean sea level in the Grampians, with a temperature of 65°F., was four degrees warmer than London. Renfrew recorded 11·0 hr. of bright sunshine, Leuchars 8·6 hr., Montrose 7·7 hr., Dalwhinnie 7·2 hr. and Prestwick 7·1 hr. In contrast Lossiemouth to the north and most places in the Midlands and south-east England were completely sunless.

The radio-sonde ascents at Leuchars at 0800 and 1400 G.M.T. on July 15 are given in Fig. 2, wet-bulb temperature being plotted against the dry-bulb value at the same pressure level. From these ascents the air over Leuchars was too dry for thunderstorms. Presumable there was more moisture further inland in the region of convergence at the centre of the low. At Leuchars cumulonimbus clouds were first seen at 1330 to the north and north-west, with tops rising to 20,000 ft. Thunder was heard at 1505 G.M.T. A thunderstorm moved from west to east across the Leuchars area at about 1600 G.M.T. and then appeared to the observer to turn northwards over the sea. No cumulonimbus cloud was observed to the east before the arrival of the storm. There was another thunderstorm at Leuchars at 1835 while showers continued until 2045 G.M.T.

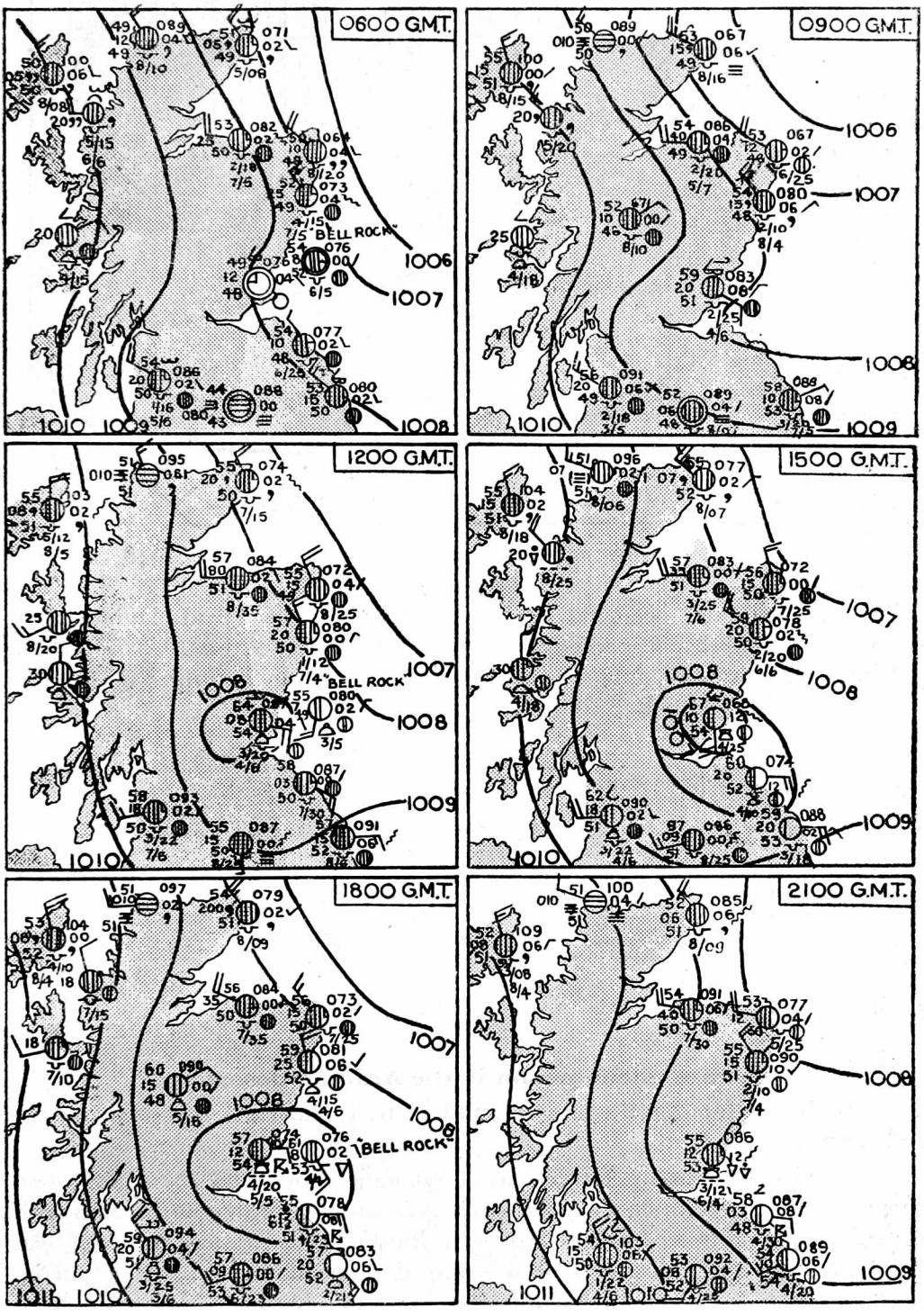


FIG. 1—SYNOPTIC CHARTS AT THREE-HOURLY INTERVALS, JULY 15, 1948

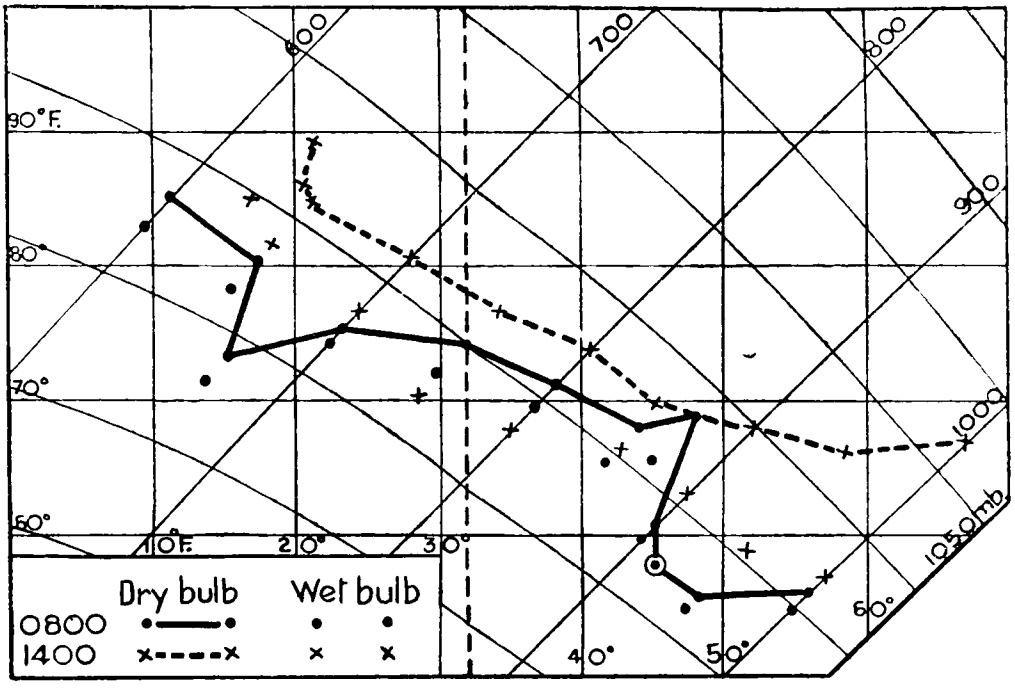


FIG. 2—UPPER AIR ASCENTS AT LEUCHARS, JULY 15, 1948

Thunderstorms also occurred at Donibristle, St. Abbs Head, Dunfermline and Dunbar. Hail accompanied the storm at Dunbar. A man was killed by lightning near Cortachy, Angus and a house was struck by lightning at Dundee.

Upper winds at Leuchars on July 15 were :—

Height	0800 G.M.T.		1400 G.M.T.	
mb.	°true	kt.	°true	kt.
700	310	7	270	11
750	320	7	290	15
800	320	12	300	14
850	320	11	290	13
900	300	6	270	9
950	270	6	260	9

W. A. L. MARSHALL

September 15, 1948

A rare phenomenon in the Arabian desert

The snowfall illustrated in the photograph by Mr. J. Durward opposite occurred on January 27, 1937.

A depression, originally formed as a secondary over the North Sea on January 19 moved south-east to south-west Asia finally uniting on the 26th with a depression which moved southwards from the Kara Sea to near the Aral Sea. The formation and movement of this last depression had caused a partial disintegration of a large anticyclonic belt covering Russia and Siberia from the 20th to 24th.

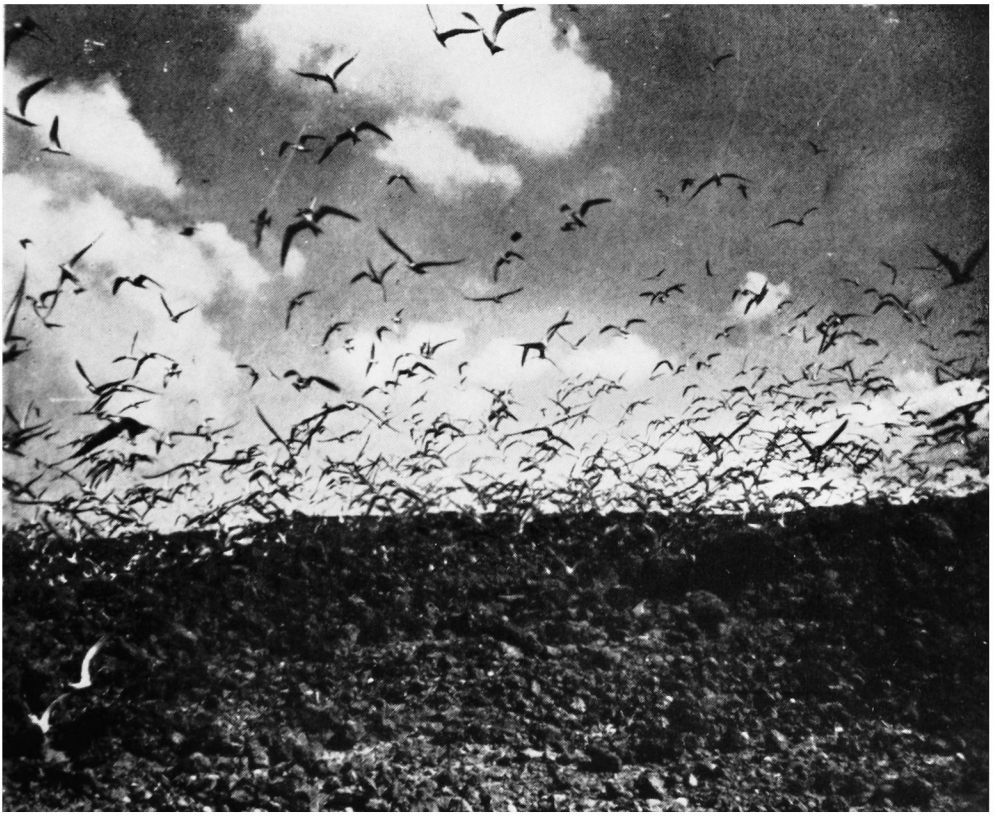
As the low-pressure area moved eastwards a cold current of polar continental air from the Kirghiz steppe swept across Iraq and north-western Arabia and led to the snowfall illustrated.

[*To face page* 148

Reproduced by courtesy of J. Durward

SNOW IN THE ARABIAN DESERT

(see opposite page)



WIDEAWAKES AT ASCENSION ISLAND

These birds form a danger to aircraft at Wideawake Field, Ascension Island. A similar danger exists with locusts in the Sudan.

To face page 149]

Reproduced by courtesy of O. M. Ashford

CIRRUS OF AN APPROACHING WARM FRONT WITH A LAYER OF ALTOCUMULUS BENEATH

This photograph was taken in the evening of July 22, 1948 ; the warm front passed through station JIG before 0300 G.M.T. next morning. The altocumulus, which was present all day, was associated with a subsidence inversion typical of " ridge " weather.

Société Météorologique de France

We welcome the appearance of a new French quarterly meteorological journal, the *Journal Scientifique de la Météorologie*, published by the Societe Météorologique de France.

The first number of the new journal consists of 31 double crown octavo pages and contains papers by M. Nicolet on some fundamental problems in radiation, by Mme. Vassy on the effect of temperature on the ozone absorption bands in the visible spectrum, by M. Kivelovitch on vertical currents, and by M. Eyraud on the effects of vertical currents on aircraft.

The new journal will appear in addition to *La Météorologie*.

OBITUARY

Mr. G. A. Clarke.—We regret to report the death of Mr. G. A. Clarke, distinguished for his work in cloud photography, on February 13, 1949.

Mr. Clarke's name is associated in the minds of all meteorologists with the city of Aberdeen whose skyline he made so familiar to them in his cloud photographs, but actually he was an Englishman born in East Anglia on September 9, 1879.

He commenced meteorological work at Kew Observatory, but in 1903 migrated to Aberdeen to take charge of the University Observatory there under the direction of the Professor of Natural Philosophy. In 1921 he became a member of the staff of the Meteorological Office. He remained at Aberdeen Observatory until he retired in 1943.

Mr. Clarke's interest in clouds and cloud photography began while he was a young assistant at Kew Observatory. Later, he became one of the two or three leading exponents of the art of cloud photography. His cloud photographs adorned practically every meteorological book published in Great Britain in the last 30 years which had anything to do with cloud description or observation. Many of his photographs are the classic examples of the types of cloud they represent. The great " International Cloud Atlas " is full of them.

Clarke was not only a superb photographer of clouds : he had a deep and wide knowledge of cloud structure, the physical causes of clouds, and the meteorological situations in which they occurred. This knowledge is most fully shewn in his major publication " Clouds : a descriptive illustrated guide book to the observation and classification of clouds " published in 1920 with an introduction by Sir Napier Shaw. The coloured plates in this book were prepared from photographs coloured by Clarke who was a good artist. On the subject of cloud photography he wrote " Instructions for taking cloud photographs " published by the International Cloud Commission in 1923, and a paper on " Cloud photography " in the " Proceedings of the Seventh International Congress of Photography 1928 ". Other papers on clouds were his analysis of cloud distribution at Aberdeen during the years 1916–18, published as Meteorological Office *Professional Notes* No. 9, and some notes in the *Meteorological Magazine*.

On meteorological subjects other than clouds he wrote a report on the climate of Aberdeenshire for the meeting of the British Association held in the city in 1934, and a note in the *Quarterly Journal of the Royal Meteorological Society*

1921 on a remarkable pilot-balloon trajectory. He had a brisk, kindly manner and it was always a pleasure to visit him at the Observatory or at his home.

Clarke was a Fellow of the Royal Meteorological Society, and of the Royal Photographic Society whose medal for the best print in the Society's exhibition he won twice.

We extend to Mrs. Clarke our deepest sympathy.

NEWS IN BRIEF

Professor O. G. Sutton, F.R.S.

Prof. O. G. Sutton, Professor of Mathematics and Physics at the Military College of Science, and formerly of the Meteorological Office, Air Ministry, was elected a Fellow of the Royal Society on March 17, 1949.

Prof. Sutton is, of course, known to all meteorologists for his work on turbulence and diffusion in the lower atmosphere.

REVIEWS

Some speculations on the resistance to the motion of cumuliform clouds, by F. H. Schmidt. *Meded. ned. met. Inst., de Bilt*, Serie B, **1**, Nr. 8. 8vo. $12\frac{1}{4}$ in. $\times$ $8\frac{3}{4}$ in., pp. 55. Rijksuitgeverij, The Hague, 1947, Price : *Fl.* 4,–.

In the " parcel " method, criteria of stability and instability are derived on the assumption that an isolated parcel of air could ascend or descend without causing any change in the environment. Bjerknes and Petterssen, however, pointed out that this was not possible and that an ascending current must have its counterpart in a descending current, and in their " slice " method derived different criteria of stability and instability. In the present paper Dr. Schmidt, in addition to criticising the basic assumptions which Petterssen made in developing the " slice " method, points out that Petterssen's conclusions are based on an equation which has been derived from the combination of two equations which cannot be satisfied simultaneously and hence cannot possibly be correct.

To rectify this defect in the " slice " method Dr. Schmidt develops another method which he calls the " column " method based on considerations of the form drag in cumuliform cloud. To obtain a quantitative solution Dr. Schmidt makes several assumptions which are very approximate and are in some cases, inconsistent. The solution, however, appears to give results which can be used in practice and qualitatively, many of the results of the " column " method are similar to those of the " slice " method. Dr. Schmidt shews that with the " column " method it is possible for the first time to reconcile Kopp's measurements of temperature within clouds with Refsdal's theoretical results.

Later in the paper Dr. Schmidt utilises the results of work on axially symmetrical jets to discuss the problem of skin-friction drag of cumuliform clouds ascending in a homogeneous atmosphere, and then attempts to combine these results with his earlier calculations of form drag to obtain a qualitative picture of a cumuliform cloud. This is not very satisfactory, as in dealing with skin-friction drag it is necessary to assume that the cumuliform cloud is stationary whereas in dealing with form drag it is equally necessary to assume that the cumuliform cloud is not stationary.

R. FROST

A first book of meteorology, by Arthur J. Starr. 8vo. 8 in. × 5¼ in., pp. 86. *Illus.* Harrap & Co., Ltd., London, 1949. Price: 5*s.* 0*d.*

This little book gives a simple introduction to meteorology, assuming hardly any knowledge of physics. Within its limits it is accurate which is more than can be said of some books of this type. There are chapters on the atmosphere in general, winds, clouds, weather (formation of rain, snow, sleet, hail, thunder), fog and mist, pressure and temperature measurement, compilation of the synoptic chart, depressions and anticyclones, and weather forecasting. There is a useful appendix, with an indication of price, on instruments suitable for a school meteorological station.

It is scarcely correct to say that J. Bjerknes deduced the familiar frontal weather sequence from theory. The author was unfortunate in publication at the time of change of the international code; he gives the old code. More care might have been taken in proof reading.

This book costs twice as much as " Meteorology for pilots and navigators ", which is of about the same level of difficulty but contains more information, though it is, perhaps, presented in a less attractive way.

G. A. BULL

Weather forecasting, by Inst. Cdr. S. W. C. Pack. 8vo. 9¼ in. × 6 in., pp. 192. *Illus.* Longmans, Green & Co., London, 1948. Price 25*s.* 0*d.*

The author states that he intends the book to provide an introduction to students who are about to specialise in meteorology and considers that it will also be of general interest to senior students in schools. The book covers the wide field of meteorology as it concerns weather forecasting, but perhaps too much emphasis at times is laid on the rules of forecasting rather than on the underlying physical processes. The general scope of the volume is probably more suitable for those taking the Civil Air Navigators' licences or the R.A.F. equivalent.

The book deals well with atmospheric stability and instability and the use of the tephigram in the prediction of convection cloud. Good diagrams give a clear expression to the chapter on the change of wind with height. The chapters on upper-level charts and forecasting in the tropics are very clearly explained.

The book is well produced and the diagrams and photographs throughout are clear and informative. However, it is considered that in an introduction to forecasting more emphasis should be laid on the convective, radiative and conductive processes as effecting the atmosphere and the importance of the sun's heating and the water vapour on the weather processes in the atmosphere. Also a fuller discussion on fundamental properties such as dry-bulb, dew-point and wet-bulb temperatures, etc., and their degree of conservatism for the various processes taking place in the atmosphere requires a place in a book on weather forecasting.

The book is not long and, although it is well produced, the price is considered rather excessive. It does not contain nearly as much information as the Meteorological Office publication " Meteorology for Aviators " which costs 7*s.* 6*d.* and the more advanced book " Meteorology, theoretical and applied " by Hewson and Long which costs $4.75.

R. E. FARMS

Symposium on searchlights. 8vo. $9\frac{3}{4}$ in. × 6 in. pp. 164. *Illus.* Published by the Illuminating Engineering Society, Argus Press, London. 1948. Price : 17*s.* 6*d.*

This book contains six papers by different authors, dealing with various problems encountered in the design and use of searchlights during the war. Five of the papers were read before the Illuminating Engineering Society on April 15, 1947, and an account of the discussion which followed is also included.

Three papers cover various aspects of searchlight design, and include technical data of the types in current use. It is interesting to see that the carbon arc is still used almost exclusively as a light source, though invented over a century ago. Several searchlights for aircraft use are described which produced, for short periods, intensities little inferior to those of ground searchlights, *i.e.* several hundred million candles.

After an informatory paper on the photometry of searchlights come two papers of more direct interest to meteorologists, dealing with the visibility of targets in a searchlight beam. Both horizontal (naval) and anti-aircraft beams are considered, and the useful range of various searchlights is calculated for a variety of targets and atmospheric conditions. The scatter coefficient of the atmosphere is found to be the overriding factor in limiting the range, so much so that even the most powerful naval searchlight is almost useless if the meteorological visibility is less than about 3,000 yd.

Meteorologists have long used searchlights to measure cloud height, and more recently to measure visibility. Future work in these fields will probably demand bigger and better searchlights, and many of the problems which will then arise will be found already answered in this symposium.

J. R. BIBBY

Everybody's weather book, by Reginald M. Lester. 16mo. 8 in. × 5 in. *Illus.* xx + 235. Sampson Low, Marston & Co., Ltd., London. 1948. Price 15*s.* 0*d.*

This small book by Mr. Lester sets out to introduce to the man-in-the-street the general mechanism of the weather and how it is observed and forecast. It makes no pretensions of being a text-book—indeed it is neither scientific nor accurate—and only describes the more elementary features of the weather, and just touches the fringe of frontal and air-mass analysis in a few odd pages.

In the beginning Mr. Lester describes briefly how weather information is collected in this country, and then tries to interest the reader in recognition of various types of weather sequence, in the types of clouds and the behaviour of the barometer during the sequence. He then considers some of the more unusual weather phenomena such as exceptionally heavy rains and auroras, and goes on to discuss the importance of weather and its irregularities to plants, birds and insects, to the farmer, and the water-engineer. He closes with chapters on weather over the oceans and over the continents, a discussion of the relation of the sun-spot cycle with weather " cycles ", and a final description of what an amateur meteorologist like himself can learn from such observations as rainfall, pressure, and temperature.

The whole book is written in a gossipy fashion even including the rumour of seaweed in the forecast room at the Central Forecast Office and such old weather saws as:

" Rain before seven,
Fine before eleven."

Particularly interesting were the " Folkestone pillars " (" a series of towering conical cloud-banks rising up from an especially dense base "—apparently altocumulus castellatus) which are " invariably " followed by rain throughout the next day over the Bristol Channel, although the " showery type of weather does not usually set in until the next day but one " when they appear off the Kentish or Essex coast. It is interesting also to learn of the danger of being suddenly crushed to death by the force of cosmic radiation in the stratosphere.

Some of the cloud photographs have not reproduced too well: those of cirrocumulus and cumulonimbus are unrecognisable. Mr. Lester is unfortunate, too, in that some of his tables of cloud forms are now out of date and there is a mistake in his conversion of degrees Centigrade to Fahrenheit.

P. B. SARSON

BOOKS RECEIVED

Apia Observatory, Annual Report for 1939. New Zealand Department of Scientific and Industrial Research. 8vo. $9\frac{3}{4}$ in. × $6\frac{1}{2}$ in. pp. iv + 149. Wellington, 1948. Price: 5*s*.

Observations made at the Royal Magnetic and Meteorological Observatory at Batavia, by H. P. Berlage, Jr. Vol. LXIII C, 1940 : Results of meteorological observations for the period 1866–1940. 4to. $12\frac{1}{2}$ in. × $9\frac{3}{4}$ in. pp. 43. Surabaya [1948].

Annuaire. 97*ième année.* A: *Météorologie* 1945. Koninklijk Nederlands Meteorologisch Instituut. 4to. $13\frac{1}{2}$ in. × $9\frac{1}{2}$ in. pp. 82. Staatsdrukkerij- en Vitgererijbedrijf. The Hague, 1948. Price : *fl.* 2.60.

ERRATUM

April 1949, PAGE 100, line 47 : *for* equator^3 *read* equator^2.

WEATHER OF MARCH 1949

After a deep depression had moved south-eastwards across the northern part of the North Sea during the early hours of the 1st, an Atlantic anticyclone advanced to western Ireland by the morning of the 2nd, but soon moved away southwards. On the 7th and 8th a depression moved south-eastwards not far to the south-west of the British Isles, and others moved eastwards not far to the north of Scotland on the 13th and south-eastwards across the Orkneys on the 17th. Then for several days an anticyclone persisted off our south-west coasts, and this spread over the British Isles on the 22nd. Pressure was rather high during the rest of the month, although the highest pressure was generally further to the north or north-east.

Mean pressure for the month was above 1020 mb. from Poland westwards across England and Ireland nearly to 50°W., and between 1015 mb. and 1020 mb. over most of North America. It was above normal over most of Europe and the north-eastern part of the North Atlantic, by more than 10 mb. in Ireland and the Hebrides and for more than a thousand miles west-south-westward of Ireland ; it was generally about normal in North America.

The weather over the British Isles was generally dry ; there was less sunshine than usual in the eastern districts of England while it was very sunny locally in the north-west of the British Isles. Cold weather prevailed during the first 12 days but from the 13th to the 26th it was generally warm. The closing days were warm in the west but cool elsewhere.

On the 1st a deep depression over Denmark moved away eastwards ; in its rear the northerly gradient was steep and northerly gales in the North Sea caused exceptionally high tides in the Thames estuary and consequent severe flooding. Subsequently an anticyclone moved south-south-east from north-west of Scotland giving a short period of cold, sunny weather. On the 3rd a trough of low pressure moving north-east caused rain in many districts but the rain did not reach most of England until night. An unsettled cold spell ensued with troughs from Atlantic depressions moving east over the country ; precipitation occurred at times, rainfall amounting to more than 1 in. locally on each day from the 3rd to the 6th. Snow occurred at times, being widespread on the 5th ; it was 4 in. deep at Blackpool on the 5th and 3 in. at Whipsnade on the 6th and 7th. On the 8th and 9th a depression off south-west Ireland moved slowly south ; snow occurred rather widely and level snow was 3 in. deep at Harrogate on the 8th. At Malham Tarn (1,297 ft. above M.S.L.) in West Yorkshire level snow was 6 in. deep on the 8th with drifts of 18 in., while on the 9th there were drifts of 5 ft. In the rear of this depression a belt of high pressure developed to the north of Scotland and moved south giving a fair day in most parts on the 10th, but a trough off our north-west coasts moving south-east caused rain generally and gales at a few exposed stations in Scotland on the 11th and 12th. Subsequently a deep depression over Thorshaven moved east to the Baltic, while secondaries moved rapidly east or south-east over the British Isles causing local gales and some precipitation on the 13th and 14th. Thereafter pressure was high on the Atlantic and a depression south-west of Iceland moved south-east to Denmark and thence to central Europe ; showery weather prevailed in the British Isles, with local gales but long bright periods. On the 20th and 21st troughs moving east over the country were associated with fairly general rain.

A change of type occurred on the 22nd when the anticyclone off our south-west coasts moved north-east and subsequently east to central Europe. Dry, mild, mainly fair weather prevailed, apart from fog, until the 26th. On the 26th and following days a new anticyclone south of Iceland moved east to Russia ; weather continued dry, but dull and cold, with considerable fog in eastern and central districts but warm and very sunny locally in the west. At Eskdalemuir, for example, the maximum temperature was 63°F. on the 30th and 65°F. on the 31st, while the corresponding values at Gorleston were 42°F. and 41°F. At Eskdalemuir too, the total sunshine for the last two days was 20·6 hr.

The general character of the weather is shown by the following provisional figures :—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	69	18	−0·7	66	−6	99	32
Scotland	67	15	+0·1	76	−3	110	32
Northern Ireland ..	64	24	+1·4	85	−6	110	33

RAINFALL OF MARCH 1949

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	·84	46	*Glam.*	Cardiff, Penylan ..	1·87	59
Kent	Folkestone, Cherry Gdn.	·92	42	*Pemb.*	St. Ann's Head ..	2·28	84
,,	Edenbridge, Falconhurst	1·19	48	*Card.*	Aberystwyth	2·34	85
Sussex	Compton, Compton Ho.	1·97	71	*Radnor*	Tyrmynydd	3·41	64
,,	Worthing, Beach Ho.Pk.	1·23	64	*Mont.*	Lake Vyrnwy	2·46	54
Hants	Ventnor, Roy. Nat. Hos.	2·10	102	*Mer.*	Blaenau Festiniog ..	5·64	65
,,	Bournemouth	1·48	64	*Carn.*	Llandudno	1·66	82
,,	Sherborne St. John ..	1·51	67	*Angl.*	Llanerchymedd ..	2·40	81
Herts.	Royston, Therfield Rec.	1·15	63	*I. Man.*	Douglas, Borough Cem.	4·05	137
Bucks.	Slough, Upton	1·27	72	*Wigtown*	Port William, Monreith	2·68	94
Oxford	Oxford, Radcliffe ..	1·70	103	*Dumf.*	Dumfries, Crichton R.I.	1·59	53
N'hant.	Wellingboro', Swanspool	1·38	77	,,	Eskdalemuir Obsy. ..	2·49	51
Essex	Shoeburyness	·75	56	*Roxb.*	Kelso, Floors	1·09	56
Suffolk	Campsea Ashe, High Ho.	·71	42	*Peebles*	Stobo Castle	1·54	53
,,	Lowestoft Sec. School ..	1·49	93	*Berwick*	Marchmont House ..	1·35	51
,,	Bury St. Ed., Westley H.	·99	52	*E. Loth.*	North Berwick Res. ..	·87	46
Norfolk	Sandringham Ho. Gdns.	1·31	69	*Midl'n.*	Edinburgh, Blackf'd. H.	·80	41
Wilts.	Bishops Cannings ..	1·26	56	*Lanark*	Hamilton W. W., T'nhill	1·44	52
Dorset	Creech Grange.. ..	1·47	52	*Ayr*	Colmonell, Knockdolian	2·49	74
,,	Beaminster, East St. ..	1·43	49	,,	Glen Afton, Ayr San ..	..	..
Devon	Teignmouth, Den Gdns.	1·21	47	*Bute*	Rothesay, Ardencraig	3·30	92
,,	Cullompton	1·65	60	*Argyll*	L. Sunart, Glenborrodale	4·37	79
,,	Barnstaple, N. Dev. Ath.	1·85	71	,,	Poltalloch	3·52	92
,,	Okehampton, Uplands	1·74	42	,,	Inverary Castle ..	4·91	77
Cornwall	Bude School House ..	1·73	71	,,	Islay, Eallabus ..	3·68	96
,,	Penzance, Morrab Gdns.	1·81	57	,,	Tiree	3·15	94
,,	St. Austell, Trevarna ..	2·45	71	*Kinross*	Loch Leven Sluice ..	1·40	47
,,	Scilly, Tresco Abbey ..	1·75	67	*Fife*	Leuchars Airfield ..	1·32	68
Glos.	Cirencester	1·79	77	*Perth*	Loch Dhu	..	..
Salop.	Church Stretton ..	2·00	83	,,	Crieff, Strathearn Hyd.	1·64	51
,,	Cheswardine Hall ..	2·73	129	,,	Blair Castle Gardens ..	1·99	72
Staffs.	Leek, Wall Grange P.S.	2·15	79	*Angus*	Montrose, Sunnyside ..	1·25	60
Worcs.	Malvern, Free Library	1·22	63	*Aberd.*	Balmoral Castle Gdns...	1·55	54
Warwick	Birmingham, Edgbaston	1·57	82	,,	Dyce, Craibstone ..	2·74	103
Leics.	Thornton Reservoir ..	1·84	100	,,	Fyvie Castle	2·77	102
Lincs.	Boston, Skirbeck ..	·94	60	*Moray*	Gordon Castle	2·80	121
,,	Skegness, Marine Gdns.	·74	45	*Nairn*	Nairn, Achareidh ..	1·92	104
Notts.	Mansfield, Carr Bank ..	1·05	50	*Inv's*	Loch Ness, Foyers ..	2·64	82
Ches.	Bidston Observatory ..	2·09	110	,,	Glenquoich	5·44	56
Lancs.	Manchester, Whit. Park	1·77	78	,,	Fort William, Teviot ..	4·24	63
,,	Stonyhurst College ..	2·44	66	,,	Skye, Duntuilm ..	3·08	70
,,	Blackpool	1·98	83	*R. & C.*	Ullapool	1·78	44
Yorks.	Wakefield, Clarence Pk.	1·15	64	,,	Applecross Gardens ..	3·89	83
,,	Hull, Pearson Park ..	1·06	58	,,	Achnashellach	6·52	96
,,	Felixkirk, Mt. St. John	1·52	77	,,	Stornoway Airfield ..	2·57	66
,,	York Museum	1·45	86	*Suth.*	Lairg	3·11	100
,,	Scarborough	1·06	59	,,	Loch More, Achfary ..	6·57	102
,,	Middlesbrough.. ..	1·02	65	*Caith.*	Wick Airfield	3·48	153
,,	Baldersdale, Hury Res.	1·09	35	*Shetland*	Lerwick Observatory ..	3·52	111
Norl'd.	Newcastle, Leazes Pk. ..	·69	33	*Ferm.*	Crom Castle	2·32	75
,,	Bellingham, High Green	·85	29	*Armagh*	Armagh Observatory ..	2·11	90
,,	Lilburn Tower Gdns. ..	·83	31	*Down*	Seaforde	2·03	70
Cumb.	Geltsdale	1·33	48	*Antrim*	Aldergrove Airfield ..	2·19	87
,,	Keswick, High Hill ..	1·28	28	,,	Ballymena, Harryville..	2·63	83
,,	Ravenglass, The Grove	2·84	92	*L'derry*	Garvagh, Moneydig ..	2·79	89
Mon.	Abergavenny Larchfield	1·50	49	,,	Londonderry, Creggan	3·39	106
Glam.	Ystalyfera, Wern House	3·29	61	*Tyrone*	Omagh, Edenfel ..	2·62	83

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, NOVEMBER 1948

Stations	Pressure		Temperatures							Relative humidity	Mean cloud amount	Precipitation			Bright Sunshine	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily Mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1022·8	+8·9	61	25	50·5	40·3	45·4	+1·6	42·9	93	7·3	1·59	−0·63	9	2·3	26
Gibraltar	1024·1	+6·1	75	50	67·2	58·3	62·7	+2·7	59·4	88	6·8	0·06	—	2	4·5	44
Malta	1020·4	+4·5	77	44	67·1	56·3	61·7	−2·2	59·6	72	6·2	5·56	—	15	5·9	58
St. Helena	1016·6	+0·1	69	52	65·4	55·0	60·2	+1·5	54·9	94	9·3	0·49	−0·75	6	—	—
Freetown, Sierra Leone	1012·0	—	89	70	85·5	72·8	79·1	—	74·5	88	7·0	5·56	—	9	—	—
Lagos, Nigeria ..	1011·5	+1·4	91	68	87·9	70·4	79·1	−2·6	76·8	85	8·2	1·84	—	7	5·9	50
Kaduna, Nigeria ..																
Chileka, Nyasaland	1014·3	+0·6	97	60	87·1	67·6	77·3	−0·4	67·2	61	5·3	4·38	+0·56	9	6·7	52
Lusaka, Rhodesia ..	1012·1	+0·8	90	55	81·9	63·3	72·6	−1·6	63·8	71	7·0	5·80	+1·57	11	6·1	48
Salisbury, Rhodesia ..	1013·8	+0·6	89	48	80·0	59·4	69·7	−0·5	60·2	64	4·0	5·47	+1·45	10	6·1	47
Cape Town ..	—	—	92	49	—	—	—	—	—	—	—	0·31	−0·78	5	—	—
Germiston, South Africa	1014·3	+1·4	81	43	74·4	54·0	64·2	−1·7	55·1	64	4·7	3·78	−0·59	14	8·4	63
Mauritius																
Calcutta, Alipore Obsy.	1014·0	+0·6	91	63	84·7	69·1	76·9	+3·4	69·7	85	5·3	3·64	+2·99	6	5·9	53
Bombay	1010·0	−2·0	95	71	88·7	75·8	82·3	+1·7	74·1	77	5·1	4·54	+4·09	5	7·9	71
Madras	1011·2	−0·1	94	72	86·4	74·8	80·6	+1·7	75·8	88	6·7	8·54	−5·07	13	7·4	64
Colombo, Ceylon ..	1010·7	+0·7	88	71	86·4	73·5	79·9	−0·1	74·6	91	6·4	12·32	+0·56	18	7·3	62
Singapore	1010·7	+1·3	91	72	86·2	73·9	80·1	−0·5	75·7	86	8·5	11·87	+1·96	22	—	—
Hongkong	1020·0	+2·4	80	53	72·9	61·6	67·3	−2·3	60·4	68	—	0·15	−1·59	4	7·1	64
Sydney, N.S.W. ..	1011·9	−1·9	97	51	71·9	58·9	65·4	−1·6	59·6	61	6·1	0·82	−2·03	12	8·1	58
Melbourne	1010·4	−4·0	89	41	70·4	49·4	59·9	−1·4	53·6	55	6·2	1·96	−0·27	12	6·9	49
Adelaide	1012·0	−3·3	92	43	73·8	53·5	63·7	−3·3	55·2	52	5·7	1·22	+0·08	11	7·9	57
Perth, W. Australia	—	—	97	44	75·6	54·6	65·1	−1·0	58·4	56	5·5	1·97	+1·17	6	9·4	68
Coolgardie	1012·2	−1·2	101	39	82·1	53·4	67·7	−3·0	54·4	40	4·0	0·10	−0·49	2 0	—	—
Brisbane	1012·9	−1·7	93	56	82·0	65·0	73·5	0·0	65·2	62	5·2	1·35	−2·38	7	9·1	71
Hobart, Tasmania ..	1007·5	−2·1	76	39	63·2	46·4	54·8	−2·4	50·4	61	8·0	2·50	+0·03	19	6·1	42
Wellington, N.Z. ..	1011·6	−0·5	71	41	61·8	48·6	55·2	−0·4	52·7	78	8·3	4·27	+0·75	13	6·3	44
Suva, Fiji	1009·1	−2·0	86	69	82·4	72·6	77·5	+0·4	74·3	85	8·0	5·50	−4·29	21	4·7	36
Apia, Samoa ..	1008·6	−0·5	89	71	85·9	73·9	79·9	+0·2	77·6	78	6·0	16·01	+5·63	22	7·4	58
Kingston, Jamaica ..	1012·3	−0·1	92	70	89·6	72·7	81·1	+1·8	74·9	77	2·9	2·49	−0·54	7	8·1	72
Grenada, W. Indies	—	—	88	72	85·0	76·0	80·5	+1·0	76·7	80	8·3	9·25	+0·79	24	—	—
Toronto																
Winnipeg																
St. John, N.B. ..																
Victoria, B.C. ..																